Workplace Demands, Economic Reward, and Progression of Carotid Atherosclerosis

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Background Characteristics of the work environment have been associated with cardiovascular morbidity and mortality, but it is unclear whether these factors are associated with preclinical manifestations of disease.

Methods and Results We investigated the association between job demands, economic reward, and the 4-year progression of carotid atherosclerosis in a population-based sample of 940 Finnish men. Data from the Kuopio Ischemic Heart Disease Risk Factor Study were used to estimate changes in plaque height, maximum and mean intima-media thicknesses across combinations of job demands, and income. Associations were examined in relation to atherosclerotic risk factors and were stratified by baseline levels of atherosclerosis and prevalent ischemic heart disease. Men who had jobs with high demands and low economic rewards had significantly greater 4-year progression of plaque height (0.33 mm, P = .008) and maximum intima-media thickness (0.32, P = .03) than men with low-demand, high-income jobs. The magnitude of these differences was not greatly attenuated by risk factor adjustment and did not differ when examined by the level of workplace resources, social support, or employment status. Larger differences were observed in a subsample of men who had more advanced atherosclerosis at baseline.

Conclusions These results show that men with demanding work that produces little economic reward have significantly greater progression of carotid atherosclerosis than more advantaged men. The relationship between job demands and health should be understood in a broad framework of interacting economic conditions, social circumstances, and behaviors that cascade over the life course and may ultimately contribute to socioeconomic inequalities in morbidity and mortality. (Circulation. 1997;96:302-307.)

Key Words • work • income • stress • atherosclerosis • ultrasound

Reports about the effects of poor working conditions on health date back to at least the 12th century, when in medieval Europe, Paracelsus noted unusually high rates of disease in miners.1 In England, Engels2 argued that employment in the factories of the industrial revolution had deleterious health consequences for the working class. More recently, studies have shown that organizational, psychological, and social features of the work environment are associated with cardiovascular morbidity and mortality.3,4 However, it is unclear whether this association is apparent only late in the natural history of cardiovascular disease, is caused by selection factors, or is the result of precipitation of clinical manifestations. Currently, few data address whether workplace factors are important in the underlying process of atherosclerosis itself.5 Ultrasound scanning of the carotid arteries has enabled the noninvasive study of the prevalence and development of atherosclerosis in population groups.6,7 B-mode imaging of intima-media thickness (IMT) in the carotid arteries is a valid indicator of generalized atherosclerosis, is a reliable method that correlates well with the extent of disease in the coronary arteries, and has predictive validity with regard to risk of coronary and cerebrovascular events.7,13

This study is, to the best of our knowledge, the first to examine the association between workplace factors and the 4-year progression of carotid atherosclerosis using three indicators of the atherosclerotic process: maximum IMT, plaque height, and mean IMT. In earlier studies, we reported both cross-sectional14 and prospective15 inverse associations between measures of socioeconomic status and IMT. It is also possible that the level of economic rewards potentiates the impact of work demands. In light of these findings and the fact that low socioeconomic status groups are likely to have higher lifetime exposure to poor working conditions, we assessed the interaction of job conditions and socioeconomic status (measured by income) on IMT progression. Extensive information on baseline levels of atherosclerotic risk factors and prevalent disease enabled the association between workplace demands, economic reward, and atherosclerotic progression to be examined with adjustment for known risk factors and stratified by both prevalent ischemic heart disease (IHD) and the extent of atherosclerosis at baseline.

Methods Subjects were participants in the Kuopio Ischemic Heart Disease Risk Factor Study, which was designed to investigate previously unestablished risk factors for IHD, carotid atherosclerosis, and related outcomes in a population-based sample of eastern Finnish men.16 Of the 3433 eligible men who were 42, 48, 54, or 60 years of age and resided in the town of Kuopio or its surrounding communities, 198 were excluded because of
death, serious disease, or migration from the area. Of the remainder, 2682 (82.9%) agreed to participate in the study. Baseline examinations were conducted between March 1984 and December 1989. No marked sociodemographic differences have been found between participants and nonparticipants.17

At baseline, subjects were recruited in two waves. The first group comprised 1516 men 54 years of age; the second comprised an age-stratified sample of 1116 men who were 42-48, 54, or 66 years of age. Ultrasonographic assessment of carotid atherosclerosis at baseline was conducted between February 1987 and December 1989 on the second wave of participants only. There were no systematic differences between the two waves of recruitment for the study other than the differences in age distribution. A 4-year follow-up examination was conducted between March 1991 and December 1993 on those men who had previously undergone ultrasonographic examination of the carotid arteries at baseline. Follow-up examinations were conducted during the same month as the baseline and at the same time of day. Mean follow-up was 4.2 years (range, 3.9 to 4.7 years). Of the 1229 participants who were eligible for the follow-up exam, 52 had died, were suffering from severe illness, or had migrated from the area. Of the remaining, 139 could not be contacted or refused to participate. Information on workplace demands, economic reward, progression of carotid atherosclerosis, and covariates was available for 940 men. There were 221, 228, 258, and 233 men in the 42-, 48-, 54-, and 60-year-old age groups, respectively. In this sample, 71 men acted as control subjects, and 68 men were participants in the treatment group of an unrelated clinical trial of pravastatin.18

Assessment of Carotid Atherosclerotic Progression

Atherosclerotic progression was assessed with high-resolution B-mode ultrasonographic scanning of a 1.0- to 1.5-cm section of the left and right common carotid arteries (CCAs) below the carotid bulbs. Images were focused on the posterior (far) wall with the subject supine. At baseline, ultrasonographic scanning was conducted by use of the ATL UM4 duplex ultrasonic system with 10-MHz sector transducer (Advanced Technology Laboratories). The Blossom Phase 2 equipped with an 8- to 10-MHz annular array probe was used at the 4-year follow-up examinations. Wedge phantoms of sun and mean IMT. Baseline IMT recordings were also classified by one physician into four categories: (1) no atherosclerotic lesion, (2) intimal-media thickening, (3) nonstenotic plaque, and (4) large, stenotic plaque. “Intima-media thickening” was defined as >1.0 mm between the lumen-intima interface and the media-adventitia interface in the CCAs below the carotid bulbs. Nonstenotic plaque was defined as a distinct area of mineralization or focal protrusion into the lumen. A plaque was defined as stenotic if it obstructed >20% of the lumen diameter.19

Assessment of Workforce Demands and Economic Reward

At the baseline examinations, participants completed detailed questionnaires that included items on aspects of their work environment and income. Items that conformed to important theoretical domains discussed in the literature were considered for inclusion in the measurement of workplace demands.4 In accordance with suggestions made in this literature, items on risk of unemployment, accidents, and physical exertion were included to supplement the questions about psychological demands. Participants were asked to rate on a Likert-type scale (0 to 4) how much mental stress or stress each of the following things caused them at work: excessive supervision of time schedules, troublesome supervisors, troublesome fellow workers, job responsibility, poorly defined tasks and responsibilities, risk of accidents, risk of unemployment, irregular work schedules, and the mental strain of work. They also were asked how often they had work deadlines and how much stress this caused them and were requested to rate the physical strain of their work. Scores for the demands scale were imputed on the basis of an average of nonmissing values for men who had no more than two missing items (n=63). Men who had more missing information than this were excluded from the analyses (n=42). The 11 individual items were dichotomized at the midpoint of the rating scale so that only when men reported that the particular aspect of work caused them more than “average” strain or stress were their responses considered positive. The 11 dichotomized items were then summed to form the workplace demands scale, which had high internal consistency (Cronbach’s α = 0.78). The scale was dichotomized so that men in the top 30% of total workplace demands were considered “high.” In previous analyses, this dichotomization had been shown to predict mortality and acute myocardial infarction in this population.21 Economic reward was assessed by self-reported income, which was dichotomized so that the lowest 20% of income earners were considered “low.” Previous analyses in the same population had shown that men in the bottom quintile of the income distribution had accelerated progression of atherosclerosis11 and also were at greatly elevated risk of mortality and acute myocardial infarction.22

Assessment of Covariates

Lipoproteins were separated from unfrozen plasma within 3 days of sampling. HDL and LDL fractions were separated from fresh plasma by use of both ultracentrifugation and precipitation. The cholesterol content of all lipoprotein fractions was measured enzymatically (CHOD-PAP cholesterol method, Boehringer Mannheim) on the day after the last spin.23 Blood pressure was measured with a random-zero sphygmomanometer with participants in both supine and sitting positions after 5-
minute rests in each position. Three systolic and diastolic pressures were taken and averaged. Average systolic pressure was used in this analysis. Body mass index was calculated by dividing the subject’s weight by the square of his height (kilogram per square meter). Alcohol consumption was assessed by instructed dietary recording for a 4-day period and for the previous 12 months by a self-administered questionnaire. Smoking was measured by questionnaire, and participants were classified for this analysis as never smoked, former smoker, and current smoker (measured in pack-years). Treatment for hypertension or hyperlipidemia was assessed by a review of medications.

Assessment of Prevalent IHD

Subjects were considered to have prevalent IHD at baseline if they had any history of prior myocardial infarction or angina pectoris, currently used antianginal medication, or had positive findings of angina from the London School of Hygiene Cardiovascular Questionnaire.

Statistical Methods

The association between workplace demands, economic reward, and progression of IMT was assessed by estimating the mean change in each measure of IMT (maximum thickness, mean thickness and plaque height) for each combination of demands and economic reward. The analyses were conducted by use of the GLM procedure in SAS version 6.09 on a Sun Sparc Station II. This procedure allows age-adjusted, least-squares mean values of IMT to be estimated and contrasted for each combination of demands and economic reward while simultaneously controlling for baseline IMT and other covariates.

We were interested in comparing differences in mean IMT progression between the low-demand, high-income group (reference category) and the low-demand, low-income; high-demand, high-income; and high-demand, low-income groups. These three pairwise contrasts were adjusted for multiple comparisons with Holm’s procedure as described by Aickin and Gensler. In addition to age, baseline levels of IMT, and covariates, all estimates were adjusted for participation in the clinical trial of pravastatin, the zooming degree of the ultrasound scan, and separate indicator variables for the individual technicians who conducted the scans.

Results

Table 1 provides mean ± SD and prevalence (percent) for baseline levels of IMT and other covariates distributed across categories of workplace demands and economic rewards. Table 2 presents the estimated mean changes in maximum thickness, plaque height, and mean thickness of the intima-media complex by work demands and income, with adjustment for age and baseline levels of IMT (model 1) and further adjustment for covariates (HD, LDL, triglycerides, systolic blood pressure, smoking, body mass index, alcohol consumption, and treatment for hyperlipidemia and hypertension) in model 2.

Workplace Demands, Economic Reward, and IMT Progression

The impact of workplace demands on atherosclerotic progression of maximum IMT and plaque height depended on the level of economic rewards (see the Figure). There were important interactions between workplace demands and economic rewards in relation to the progression of maximum IMT (cross-product interaction term, \(P = .18\)) and plaque height (cross-product interaction term, \(P = .02\)), but this effect was not observed for changes in mean IMT. Men with high levels of workplace demands and low economic rewards had significantly greater average progression in the maximum wall thickness of the tBCA (0.32 mm, \(P = .03\)) compared with men with low demands and high economic rewards (0.26 mm). Men with high demands and low economic rewards also had significantly greater progression of plaque height (0.33 mm, \(P = .008\)) compared with men with low demands and high incomes (0.27 mm). These patterns were not evident in relation to changes in mean IMT, for which there was no interaction between workplace demands and economic.

<table>
<thead>
<tr>
<th>TABLE 1. Workplace Demands, Economic Reward, and Mean or Prevalence of Selected Baseline Covariates in 940 Finnish Men</th>
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</thead>
<tbody>
<tr>
<td><strong>High Work Demands</strong></td>
</tr>
<tr>
<td><strong>Low Income</strong></td>
</tr>
<tr>
<td><strong>(n=87)</strong></td>
</tr>
<tr>
<td><strong>Age, y</strong></td>
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<tr>
<td><strong>Completed high school, %</strong></td>
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<tr>
<td><strong>LDL, mmol/L</strong></td>
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<td><strong>HDL, mmol/L</strong></td>
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<td><strong>Systolic blood pressure, mm Hg</strong></td>
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<td><strong>Alcohol, g/day</strong></td>
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<td><strong>Serum triglyceride, mmol/L</strong></td>
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<td><strong>Body mass index, kg/m²</strong></td>
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<tr>
<td><strong>Baseline maximum IMT, mm</strong></td>
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<td><strong>Baseline mean IMT, mm</strong></td>
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<tr>
<td><strong>Baseline plaque height, mm</strong></td>
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</tbody>
</table>

*IMT indicates intima-media thickness. Values are mean±SD when appropriate; prevalence is given in percentage. As determined by Student's t or the χ² test for the difference between low and high income groups in each work demand category.
TABLE 2. Workplace Demands, Economic Reward, and Mean Changes in Three Measures of IMT in 940 Finnish Men

<table>
<thead>
<tr>
<th>Demands</th>
<th>Income</th>
<th>n</th>
<th>Model 1, Adjusted for Age and Baseline IMT</th>
<th>Model 2, With Additional Adjustment for Covariates</th>
</tr>
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<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Mean±SE</td>
<td>P*</td>
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<tr>
<td>Change in maximum IMT, mm</td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>High</td>
<td>Low</td>
<td>87</td>
<td>0.32±0.021</td>
<td>.03</td>
</tr>
<tr>
<td>High</td>
<td>High</td>
<td>239</td>
<td>0.26±0.012</td>
<td>NS</td>
</tr>
<tr>
<td>Low</td>
<td>Low</td>
<td>84</td>
<td>0.27±0.022</td>
<td>NS</td>
</tr>
<tr>
<td>Low</td>
<td>High</td>
<td>530</td>
<td>0.26±0.009</td>
<td>Reference</td>
</tr>
<tr>
<td>Change in plaque height, mm</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>High</td>
<td>Low</td>
<td>87</td>
<td>0.33±0.019</td>
<td>.008</td>
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<td>Change in mean IMT, mm</td>
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<tr>
<td>High</td>
<td>Low</td>
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<td>530</td>
<td>0.11±0.006</td>
<td>Reference</td>
</tr>
</tbody>
</table>

IMT indicates intima-media thickness.
*As determined by pairwise contrast with reference category (adjusted for multiple comparisons). Adjusted for HDL, LDL, triglycerides, smoking, alcohol, body mass index, systolic blood pressure, treatment for hypertension, or hyperlipidemia.

Low-income men, regardless of their levels of work demands, had a higher mean progression of IMT. The magnitude of the associations between work demands, economic rewards, and progression of maximum thickness and plaque height was largely unaffected by adjustment for atherosclerotic risk factors. In other analyses (not shown), these associations did not differ when examined by the level of workplace resources, social support at work, or employment status.

Workplace Demands, Economic Reward, and IMT Progression Stratified by Prevalent IHD and the Degree of Atherosclerosis at Baseline

Table 3 presents the associations between work demands, economic rewards, and changes in plaque height according to prevalent IHD and the extent of atherosclerosis at baseline. In men who had more advanced atherosclerosis (ie, presence of stenosis ≥20% lumen diameter or evidence of nonstenotic plaque) and prevalent IHD at baseline, the combination of high demands and low economic rewards was associated with the largest mean increases in plaque height (0.40 mm). Similarly, men with high demands and low incomes who had advanced atherosclerotic disease but no history of prevalent IHD at baseline had the largest changes in plaque height (0.40 mm), whereas men with low demands and high incomes had a mean change of only 0.24 mm. There were no differences in progression of plaque height between the demands–economic rewards groups for men who were free of IHD and had no advanced atherosclerotic disease. Although Table 3 presents only data for changes in plaque height, the pattern of results described for the analyses stratified by prevalent IHD and extent of atherosclerosis was generally consistent across the other measures of IMT progression.

Discussion

These results show that men whose work has high demands but low economic rewards have significantly greater 4-year progression of carotid atherosclerosis compared with men with low job demands and high incomes. These results are consistent with the "effort-reward imbalance" model developed by Siegrist, which suggests that work that has an imbalance between high demands, high psychological "immersion" in work roles, and low economic and psychosocial rewards is associated with poor health outcomes.

The magnitude of these relationships did not differ by the level of workplace resources and social support or by employment status and was largely unaffected by adjustment for known atherosclerotic risk factors. However, workplace demands and income are associated with baseline levels of IMT, atherogenic risk factors, and changes in those risk factors over time. Analyzing the association of demands and economic reward with changes in carotid atherosclerosis with adjustment for baseline levels of IMT and atherogenic risk factors may
be somewhat problematic. Thus, the lack of confounding effects from the atherogenic risk factors should not necessarily be interpreted as evidence that the association between high workplace demands, low income, and progression of carotid atherosclerosis is independent of these risk factors. Furthermore, we have previously reported that the cross-sectional association between income and carotid atherosclerosis in the same population was largely mediated by a similar group of atherosclerotic risk factors.14

Although these findings demonstrated a role for high work demands and low economic reward in the progression of IMT, we conducted stratified analyses to identify whether the associations differed by the extent of atherosclerosis and prevalent IHD at baseline. The combination of high job demands and low economic reward was strongly associated with larger changes in IMT, but only for men who had some degree of advanced atherosclerosis at baseline. In these subsamples, the magnitude of change did not differ by the presence of IHD at baseline. The lack of association between work demands, income, and changes in IMT for men who were free of IHD and had little evidence of atherosclerotic thickening at baseline suggests that the impact of the demands-income imbalance is more important in later stages of the disease process. Although the differential pathological importance of changes in measures of maximum thickness and plaque height remains to be clearly established, it seems reasonable to suggest that high work demands, combined with low economic rewards, are related to the development of focal lesions that protrude into the lumen and increase the surface roughness of the CCAs. The development of roughened arterial walls with steeply sided projections into the lumen can subject the lesion to increased shear stress and flow turbulence, raising the potential for plaque instability, fissuring, and possible rupture.

Several issues must be considered before conclusions can be drawn from these results. First, the measure of workplace demands used in these analyses may have been subject to a reporting bias because it was based on a self-assessment of the extent of stress or strain associated with psychosocial aspects of work. Although the most accurate assessment of job demands would be achieved by a combination of subjective and objective measures, high correlations between subjective assessments and expert ratings of job conditions have been demonstrated.39 Furthermore, we do not believe that bias in the self-reporting of job demands could explain why greater changes in arterial wall thickness were observed in men who had high demand-low income jobs, even if they were free of IHD at baseline.

Second, the assessment of job demands and economic reward was based on a single measurement and does not take into account changes in job exposures and income over time. Moreover, structural alterations to the Finnish economy have seen large increases in unemployment and changes in the occupational structure of the region both before and during the period of this study.30 However, our results were unchanged in stratified analyses (not shown) that excluded men who reported any change in job title over the last 10 years and in other analyses that excluded men who were either unemployed or retired at baseline. Third, because our findings are based on a population of men in eastern Finland, they need to be replicated in women.

This study is the first in a large unselected sample to show strong relationships between workplace factors, economic rewards, and progression of atherosclerotic vascular disease. These findings add to the evidence that factors associated with work are important in the development of atherosclerotic vascular disease before the appearance of clinically relevant and more distal manifestations of the disease process. They are entirely consistent with a previous study in this population that demonstrated that the combination of high work demands and low economic reward was prospectively
associated with a twofold increased risk of incident acute myocardial infarction.21

The differences in atherosclerotic progression between high-demand, low-income and low-demand, high-income men observed in these data have potentially important clinical and public health interpretations. Although there is little information on the relationship between carotid atherosclerotic progression and clinical events, Salonen and Salonen9 have demonstrated cross-sectionally that a 0.1-mm difference in maximum IMT was associated with an 11% increased risk of acute myocardial infarction (95% confidence interval, 6% to 16%, P<0.001).

The evidence presented here indicates that jobs with high demands and low economic rewards are associated with accelerated progression of carotid atherosclerosis. Reducing the atherosclerotic vascular disease burden associated with demanding, low-income work may require interventions that do more than target low-income workers for behavioral modification.21 Although the intent of these programs is to improve behavioral risk factor profiles, they largely ignore the fact that demanding, low-paying work is only one, albeit important, aspect of life for individuals of low social class. In this light, employment in low-paying, high-demand jobs may well be an important link in a chain of causation between lack of education and increased cardiovascular morbidity and mortality. If poor job conditions are just one of many deleterious exposures for those who receive little education, then we need to understand the relationship between job demands and health in a broad framework of interacting economic conditions, social circumstances, and behaviors that cascade over the life course31-33 and ultimately result in social class inequalities in morbidity and mortality.

Acknowledgments

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References


