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Session I: Conditions of work, stress and occupational health: Present conditions and likely future trends

'Job Strain' Findings in the Cornell University Worksite Blood Pressure Study: A Review[1, 2]

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ABSTRACT

Purpose: 'Job strain' (defined as high demands and low control) has been previously associated with increased risk of cardiovascular disease (CVD) and, cross-sectionally, with hypertension and elevated ambulatory blood pressure (AmBP). Our longitudinal cohort study was designed to investigate the hypothesis that exposure to 'job strain' is causally related to increases in mean AmBP.

Methods: The sample consists of 285 healthy male employees, aged 30–60 at initial recruitment, at 8 New York City worksites, 195 of whom were restudied 3 years after (Time 2) their initial participation. Mean systolic (AmSBP) and diastolic (AmDBP) ambulatory blood pressure at work, home and during sleep were computed from 24-hour recordings and diary entries specifying location. The relationship of 'job strain' to AmBP was examined cross-sectionally at each round of data collection. In addition, to take advantage of our information on 'job strain' status at each assessment and to evaluate the impact of changes in exposure, a 'job strain' change variable was constructed with four categories: those defined as having no 'job strain' at either Time 1 or Time 2 (N = 138), those reporting 'job strain' at both times (N = 15), and two groups which changed 'job strain' status. Multiple regression analysis was used to examine the cross-sectional associations of AmBP with 'job strain', as well as to predict 3 year change in AmBP (from Time 1 to Time 2) with 'job strain' change, controlling for age, body mass, race/ethnicity, smoking status, alcohol consumption, education, sodium and physical exertion level of the job.

Results: Cross-sectional analyses at Time 1 and Time 2 showed consistent significant effects of 'job strain' on AmBP, even though the overlap between the high strain groups at different times was less than 50%. In cross-sectional analyses, subjects with 'job strain' had work AmSBP/AmDBP

[1]This paper is based on a presentation at the "Triangular Conference" on "Work-Related Stress and Health in Three Postindustrial Settings—the European Union, Japan and the United States" held in Tokyo 31, October 1 November 1998 and several published papers.

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Key words : 'job strain', cohort, ambulatory blood pressure, occupation, etiology, epidemiology, hypertension

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which were 5–7/3–5 mmHg higher than subjects without 'job strain'. Those men facing chronic 'job strain', that is working in high strain jobs at both Time 1 and Time 2 had work AmSBP/AmDBP on average, 10–12/6–8 mmHg higher than those with no 'job strain' at either times. The two crossover groups had intermediate levels of blood pressure. Effect sizes for chronic three-year exposure to 'job strain' are larger than the estimated effect of aging 25 years or gaining 50 pounds in weight. In longitudinal analyses, subjects who changed from exposure to 'job strain' to no exposure three years later had a significant decrease in AmSBP/AmDBP of about 5/3 mmHg.

Conclusions: The previously reported cross-sectional association between 'job strain' and AmBP was replicated at follow-up three years later. Repeated exposure to 'job strain' was associated with the highest levels of AmBP's, but not with any further increases in AmBP. However, change in 'job strain' status predicted change in AmBP over a 3-year period. 'Job strain' emerges as a consistent and substantial risk factor for AmBP in men. It appears that changes in exposure to work stress over time among working men can obscure associations between stress and outcome and should be taken into account in designing studies to assess the impact of work stress on CVD.

Introduction

'Job strain', defined as the combination of high psychological demands and low decision latitude on the job, has consistently been found to be a risk factor for coronary heart disease in both cross-sectional and prospective studies[1)~4)]. The Worksite Blood Pressure Study (WSBPS) was designed to investigate the hypothesis that the reported associations between Karasek's 'job strain' measure and coronary heart disease are due in part to the impact of 'job strain' on ambulatory blood pressure (AmBP). The study began as a nested case-control design and later became a prospective cohort study. Our initial case-control findings demonstrated that employed males with essential hypertension were almost 3 times more likely than those without hypertension to report exposure to 'job strain'[5), 6)]. Among 285 men employed at eight work sites, exposure to 'job strain' was found to be associated with elevated levels of systolic and diastolic AmBP at work, at home and during sleep as well as with increased left ventricular mass index[7)].

In this article, cross-sectional results at Time 1 and Time 2 and three related analyses for subjects followed for three years of the job strain and AmBP relationship using the Time 1 and Time 2 data are reported for 195 men. The first is a replication of the original Time 1 cross-sectional analysis using the Time 2 cross-sectional data. The ability to replicate results, either across samples or, as in the present case, at another point in time, is fundamental to the scientific enterprise. The second is an examination of the impact on AmBP of repeated exposure to job strain at Time 1 and Time 2. Third, a longitudinal analysis is performed, using Time 1 and Time 2 data, designed to test the hypothesis that changes in 'job strain' are associated with changes in AmBP.

Subjects and methods

Begun in 1985, this is a prospective cohort study of working men and women conducted at eight New York City work sites, each employing at least 150 persons. These sites are: a newspaper typography department, a federal health agency, a stock brokerage firm, a liquor marketer, a private hospital, a sanitation collection agency and repair facility, a department store warehouse and the headquarters for a large insurance company. The methods for the first round of data collection (Time 1) have been reported in detail elsewhere[5)~7)]. In brief, potential subjects received a casual blood pressure screening by department at their work sites and demographic data were collected. For the employees of a department to be eligible for the study, at least 75% had to have participated in the screening.

From the screened sample, individuals were eligible to be selected for the initial case-control study if they were between 30 and 60 years old, were employed more than 30 hours/week,

were able to read English, had a body mass index less than 32.5 kg/m^2, had no second job of 15 or more hours per week and had been at their current work site for at least three years before being approached for this study and, if applicable, before being diagnosed as having high blood pressure. Based on the average of the last two (of three) casual blood pressure (BP) measurements taken during the initial work-site screening and repeated several weeks later, men who met the above eligibility criteria were divided into two groups: (1) those who had a diastolic BP (DBP) greater than 85 mm Hg or who were taking antihypertensive medication for hypertension were recruited as cases and (2) those with a DBP of 85 mm Hg or less and were not taking antihypertensive medication were eligible to serve as controls. Approximately three controls were recruited for every two cases. Individuals at work sites 2 through 7 whose DBP crossed over (initial screening DBP > 85 mmHg and recruitment session DBP <= 85 mmHg, or initial screening DBP <= 85 mmHg and recruitment session DBP > 85 mmHg) were not invited to participate.[1] Anyone who had a history of coronary, cerebrovascular, or peripheral vascular disease, electrocardiographic evidence of myocardial infarction, ischemia or atrial fibrillation, funduscopic changes, evidence of any secondary cause of hypertension, screening systolic blood pressure greater than 160 mmHg (sites 2-8) or screening diastolic blood pressure greater than 105 mmHg was also excluded from the study[5), 6)].

Of the initial 285 male subjects recruited at Time 1, 195 subjects who were alive, located and still employed, completed the Time 2 assessment. A total of 25 Time 1 participants were ineligible for the Time 2 cross-sectional and longitudinal analyses for the following reasons: 3 were deceased, 6 developed cardiovascular disease, and 16 were unemployed, disabled or retired (and therefore had no 'job strain' status). These subjects tended to be older and have higher blood pressures at Time 1 than eligible subjects at Time 2. The remaining 65 were lost to follow-up: 9 had moved out of the region or could not be located, 42 refused subsequent participation, and 14 agreed to participate but failed to complete the protocol. As described below, there were no significant differences on the Time 1 variables of interest between those lost to follow-up and those who completed the Time 2 assessment. All subjects signed an informed consent statement approved by Cornell University Medical Center's Institutional Review Board.

[1]To increase the pool of eligible subjects for the cohort study at the eighth and last site the following eligibility criteria were changed: (1) subjects were no longer recruited in a fixed ratio (2:3) of cases to controls as at the previous sites; and (2) subjects were only required to have been at their work site for one year.

Procedures

At each assessment, subjects wore an AmBP monitor for 24 hours during a normal work day, using procedures described previously[8)]. At Time 1, those currently on antihypertensive medication (n = 28 of 285) were titrated off medication and then monitored for three weeks prior to wearing the AmBP monitor. At follow-up, twelve subjects in the cohort sample (n = 195) were currently taking medication; eight were again titrated off and the remaining four wore the monitor while on medication. A Spacelabs 5200 device was used for the first seven work sites at Time 1 and a Spacelabs 90202[9)] was used for the eighth site at Time 1 and all sites at Time 2.

The monitor was attached at either the subject's work site or at the Cornell University Medical College (CUMC) Hypertension Center and calibrated by comparing five successive systolic and diastolic readings against simultaneously determined auscultatory readings taken by a trained observer with a mercury column sphygomomanometer; both had to be within 5 mmHg to be judged acceptable. The subject was instructed to proceed through a workday. The monitor was programmed to take readings every 15 minutes during awake hours and either hourly or twice per hour during anticipated sleep hours. Each time the monitor inflated and recorded blood pressure during waking hours the subject was asked to remain as motionless as possible and then to record his location, position, activity, and mood in a diary. The diary information (i.e., whether subjects reported being at work, home or asleep) was used to calculate average

Table 1 Descriptive statistics for Cornell Worksite Ambulatory Blood Pressure cohort sample at Times 1 and 2

	Time 1	Time 2
	Mean (sd)	Mean (sd)
	N = 195[1]	N = 195
Age	43.4 (8.2)	46.5 (8.3*)
Education (yrs)	14.4 (2.3)	(no change)
Body Mass Index (kg/m^2)	25.8 (2.9)	26.1 (3.1)*
24 hour urine sodium	153.0 (65.2)	140.2 (57.6)*
Job physical exertion	1.8 (0.7)	1.7 (0.8)*
Decision Latitude	36.0 (5.9)	36.3 (5.4)
Workload demands	31.9 (6.4)	31.3 (6.0)
Work Ambulatory SBP	130.1 (13.3)	129.9 (11.2)
Work Ambulatory DBP	82.3 (8.3)	82.4 (7.9)
Home Ambulatory SBP	126.2 (13.3)	127.3 (11.4)
Home Ambulatory DBP	78.7 (8.3)	79.3 (8.1)
Sleep Ambulatory SBP	112.0 (12.3)	112.6 (11.8)
Sleep Ambulatory DBP	67.0 (8.2)	66.7 (8.8)
	%	%
Race/Ethnicity:		
Caucasian	84	(no change)
African-American	8	(no change)
Hispanic	7	(no change)
Some college education	70	(no change)
Current smoker	20	18
Regular drinkers	19	21
"Lots of physical effort on the job"	18	16
Type A behavior	42	38
Job strain	21	16*

[1]The wave 1 descriptive statistics are for the 195 subjects who also participated at Time 2.
*Significantly different between Time 1 and Time 2

AmBP for each location category. When fewer than five readings were obtained at work, home or sleep, the corresponding average was treated as missing data. Five readings are considered minimally sufficient to produce reliable estimates of mean work blood pressure[10]. Most averages, except during sleep, are based on many more than five readings.

At recruitment, subjects received a routine medical examination that included a brief history, a cardiovascular physical examination, and a review of subjects' responses to a health activity questionnaire addressing alcohol intake, current smoking status, and exercise

habits. Height and weight were measured by a nurse/technician during the physical examination and/or at the time of an echocardiogram and Quetelet's body mass index (BMI) was calculated as weight (kg)/height $(m)^2$. A small blood sample was drawn to measure cholesterol, and a 12-lead EKG and an M-mode echocardiogram were performed according to standard procedures[11] at the CUMC Hypertension Center.

Subjects completed a questionnaire packet which included the Job Content Questionnaire (JCQ) to evaluate 'job strain'. The JCQ is a 42-item questionnaire developed by Dr. Robert Karasek and colleagues, based primarily on questions drawn from the U.S. Department of Labor/University of Michigan Quality of Employment Surveys[12]. Two scales were used to define 'job strain'—job decision latitude and psychological job demands. Job decision latitude, an operationalization of the concept of "job control" was defined as the sum of two subscales each given equal weight: 1) skill discretion, measured by 6 items (keep learning new things; can develop skills; job requires skill; task variety; repetitious; job requires creativity), and 2) decision authority, measured by 3 items (have freedom to make decisions; can choose how to perform work; have a lot of say on the job). Psychological job demands was defined by 5 items (excessive work; conflicting demands; insufficient time to do work; work fast; work hard). All questions were scored on a Likert scale of 1 to 4, and both decision latitude and psychological job demands were constructed to have a range of 12 to 48. Scale reliability in this sample was acceptable for both decision latitude (Cronbach's alpha = .82) and workload demands (Cronbach's alpha = .74). Previous research[13] in a nationally representative working male population indicated that about 20% of the men have jobs simultaneously high in demands and low in decision latitude, a situation labeled as 'job strain' or a "high strain job". We, therefore, selected cut off points for psychological workload and decision latitude so that about 20% of our heterogeneous study sample would also be classified as having 'high strain' jobs. Jobs were classified as 'high strain' if subjects scored 37 or below for decision latitude *and* 32 or above for psychological job demands. The medians of decision latitude and job demands were 36 and 32, respectively, at baseline (N = 285). The same criteria were used to define 'job strain' at Time 2. For the cohort analysis a 4-category composite 'job strain' variable was constructed based on subjects' reported 'job strain' status at Time 1 and Time 2. For example, at Time 2, Group 1 (N = 138) reported no 'job strain' at both Time 1 and Time 2. Those without 'job strain' at Time 1 and with 'job strain' at Time 2 are Group 2 (N = 17), while those reporting 'job strain' at Time 1 but not at Time 2 are Group 3 (N = 25). Those in Group 4 (N = 15) reported 'job strain' at both Time 1 and Time 2 and are labeled as having "chronic 'job strain'" (see Figure 1).

The same battery of psychosocial questionnaires administered at Time 1 was again administered at Time 2. The Jenkins Activity Survey was administered to evaluate Type A behavior, and subjects were classified as 'Type A' if they scored above 0. A demographic questionnaire elicited information on years of education, race, and age. Based on responses to the health activities questionnaire, subjects were classified either as non-drinkers if they reported they drink not at all or occasionally, or as regular alcohol users if they reported a) consuming alcohol at least 4 times per week, or b) binge drinking. Subjects were classified as smokers if they currently smoked. Race (ethnicity) was classified as African-American, Hispanic, Caucasian or other. Finally, physical activity on the job was evaluated by a single item from the JCQ ('job requires lots of physical effort'), scored on a 4-point Likert scale.

There are very few missing data for the subjects included in this analysis. There are no missing data on 'job strain'. Those missing data on an AmBP measure were excluded from the analyses of that measure. The modal category (or mean) was substituted for the small amount of missing data on the categorical (or continuous) covariates.

Statistical analyses for Cohort results

To test for selective attrition, the Time 1 distributions (either means and standard deviations or percentages) of 'job strain', all covariates, and the six AmBP measures for the 65 eligible non-participants at Time 2 and the 195 participants at Time 2 were compared

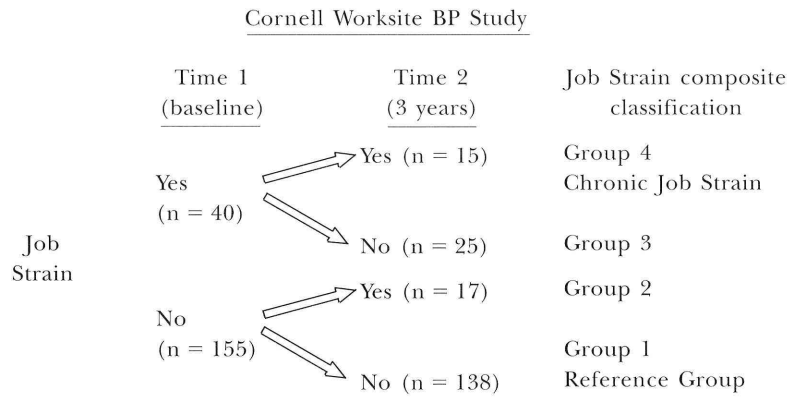

Fig. 1 Job Strain Change Groups

using t-tests and chi-square tests.

As in the previously published analysis of the cross-sectional association between 'job strain' and Time 1 AmBP[7], the replication using Time 2 data was modeled using multiple linear regression. Several known or suspected risk factors (age, BMI, race/ethnic group, alcohol use, 24-hour urine sodium excretion, Type A behavior, education level, current smoking status) and potential confounders of the hypothesized 'job strain'/blood pressure relationship (physical exertion level of the job and work site) were considered as covariates. Only those covariates that demonstrated a moderately consistent effect across time and/or location (work, home, and sleep) on either systolic or diastolic blood pressure were retained in the final analyses.

To examine the possible impact of changes in 'job strain', we initially repeated the cross-sectional analysis, replacing the contemporaneous 'job strain' dichotomy with the four-category 'job strain' change measure, and report the Time 1 and Time 2 AmBP adjusted means for each category. For the longitudinal analysis, a repeated measures regression with time-varying covariates was used to test for significant changes in AmBP as they relate to 'job strain' change. The same covariates that were controlled for in the cross-sectional analyses were again controlled, most as time-varying covariates. This analysis was performed using the state-of-the-art, maximum-likelihood estimation procedure for unbalanced designs (PROC MIXED) recently incorporated into the SAS software[14].

As described above the Cornell Worksite BP project is an ongoing prospective cohort study in New York City of employed men and women, aged 30-60. The first wave of the study consisted of a nested case-control study design, which included 262 men from eight worksites in a wide variety of white-collar and blue-collar jobtitles. Eligible cases (N = 85) had diastolic blood pressure (DBP) above 85 mm Hg at both screening and recruitment, or were taking antihypertensive medication, while controls (N = 177) had DBP less than or equal to 85 mm Hg at both screening and recruitment. Subjects not meeting these BP criteria were excluded from the Case control analysis. Other methods were as described above.

Findings:

Case-control study findings:

In the first wave of the study, participants exposed to job strain (21% of the sample) were approximately 3 times (OR = 2.7) more likely to have hypertension (being a case) than those not exposed, controlling for other possible risk factors or covariates (e.g., age, race, education, body mass index (BMI), Type A behavior, alcohol use, smoking, 24-hour urine sodium, physical exertion level of the job) as well as a potential confounder of this association (worksite)[5)~7)].

Cross-sectional results (single exposure to job strain):

Cross-sectional study results at Times 1 and Time 2

The same sample was analyzed utilizing mean ambulatory blood pressure as the out-

come rather than case-control status[7]. Using ANCOVA, job strain was associated with an elevation in work systolic blood pressure (SBP) of 7.8 mmHg ($p < .001$) and in work DBP of 5.0 mmHg ($p = .001$), after adjusting for the same risk factors and potential confounders (see Table 2). This effect persisted to home and sleep blood pressures. Job strain was also associated with an increase in left ventricular mass index (LVMI) of 9.7 g/m^2 ($p = .001$)[6), 7].

The cross-sectional results for job strain and AmBP at Time 2 were almost identical for those at Time 1 with job strain associated with an elevation of work SBP of 6.4 mmHg ($p < .001$) and with work DBP of 5.0 mmHg. Compared to Time1 when 21% (n = 55) of the sample of 285 men reported job strain, at Time2 only 16% (n = 31) of the sample of 195 reported job strain.

Table 2 Difference in AmBP[a] (mmHg) between job strain groups[b]—results of three cross-sectional analyses

	Time 1 AmBP Cohort Sample (N = 195)	**Time 2 AmBP** Cohort Sample (N = 195)
Work ambulatory BP		
Systolic	7.8***	6.4***
Diastolic	5.0***	5.0***
Home ambulatory BP		
Systolic	7.7***	6.9***
Diastolic	4.1**	4.9**

a. Group means and differences are adjusted for the effects of age, body mass index, race/ethnicity, current smoking status and alcohol consumption status, based on the cross-sectional analysis for the indicated Time and sample. Systolic BP means are also adjusted for a curvilinear (quadratic) effect of age.

b. Job strain exposure status assessed at time of AmBP assessment.

**p < .01, ***p < .001

Results for subjects repeatedly exposed to job strain (Time 1 and Time 2)

Across all 195 men with complete data at Time 1 and Time 2, the "chronic strain" group (yes-yes at Time 1 and Time 2) averaged about 8–11 mmHg SBP and 6–8 mmHg DBP higher cross-sectionally than the "low strain" group (no-no at Time 1 and Time 2.). (P-values for awake BP differences among the 4 groups are all less than .006—see Table 3). We have published these results in Psychosomatic Medicine[15].

Prospective Cohort study results: Change in AmBP

Time 1/Time 2 Cohort results:

For those who were in the high strain group at Time 1 and not at Time 2, there was a decrease in average AmBP at work and at home of about 5 mmHg systolic pressure ($p < .05$ for both locations) and 3 mmHg diastolic pressure ($p < .01$ for work, $p < .05$ for home) (see figure 2). Although the significance level of the global F-test for all four subgroups ranges from .07–.26, the consistency of the result, across location and for systolic and diastolic pressures, makes it unlikely that this pattern is attributable to chance (a Type I error). There is little evidence of a change in sleep AmBP. (Note: nearly one-third of subjects were missing data for sleep AmBP at Time 1 and/or Time 2.)

With respect to the cumulative exposure hypothesis, there is no evidence of an increase in AmBP from Time 1 to Time 2 among those in the chronic strain group. Our prediction that those in this group would exhibit a larger increase than those not having 'job strain' at both assessments is not supported (all $p > .15$).

Discussion: Job strain and AmBP

The present cross-sectional and longitudinal cohort study findings confirm and extend our previously reported results for men[2]. With the second wave of data, we again find cross-sectionally that those in high strain jobs have substantially higher systolic AmBP at work, home and during sleep, and higher diastolic AmBP at work and home compared to those not exposed to job strain. The magnitude and direction of the effects are very similar to those reported previously[7] for Time 1 partic-

[2]A third wave has added over 100 women to the sample and will provide sufficient numbers of women to test hypotheses for possible replication of the results seen in men.

Table 3 Adjusted[a] mean ambulatory blood pressures (mm Hg) at Time 1 and Time 2, by job strain change group and location

	Job Strain (Time 1, Time 2)				Signif of *F-test*
	No · No (n = 138)	*No · Yes* (n = 17)	*Yes · No* (n = 25)	*Yes · Yes* (n = 15)	
Work ambulatory BP					
Systolic, Time 1 (n = 194)	128.3	130.0	133.6	140.7	.0017
Systolic, Time 2 (n = 195)	128.5	131.5	130.2	139.6	.0015
Diastolic, Time 1 (n = 194)	81.1	82.5	84.8	88.8	.0008
Diastolic, Time 2 (n = 195)	81.3	83.2	82.8	90.4	.0002
Home ambulatory BP					
Systolic, Time 1 (n = 187)	124.2	128.9	130.2	135.7	.0007
Systolic, Time 2 (n = 181)	125.7	128.7	127.3	136.8	.0016
Diastolic, Time 1 (n = 187)	77.6	80.2	81.0	83.4	.0060
Diastolic, Time 2 (n = 181)	78.3	80.7	79.1	85.6	.0062
Sleep ambulatory BP					
Systolic, Time 1 (n = 157)	110.6	111.0	115.1	121.4	.0152
Systolic, Time 2 (n = 153)	111.4	112.1	112.9	122.2	.0336
Diastolic, Time 1 (n = 157)	66.5	67.6	67.9	70.4	.3784
Diastolic, Time 2 (n = 153)	65.9	66.4	68.1	72.1	.1054

a. All means are adjusted for age, body mass index, race/ethnicity, current smoking status and alcohol consumption status, based on the cross-sectional analysis for that Time. Systolic BP means are also adjusted for a curvilinear (quadratic) effect of age.

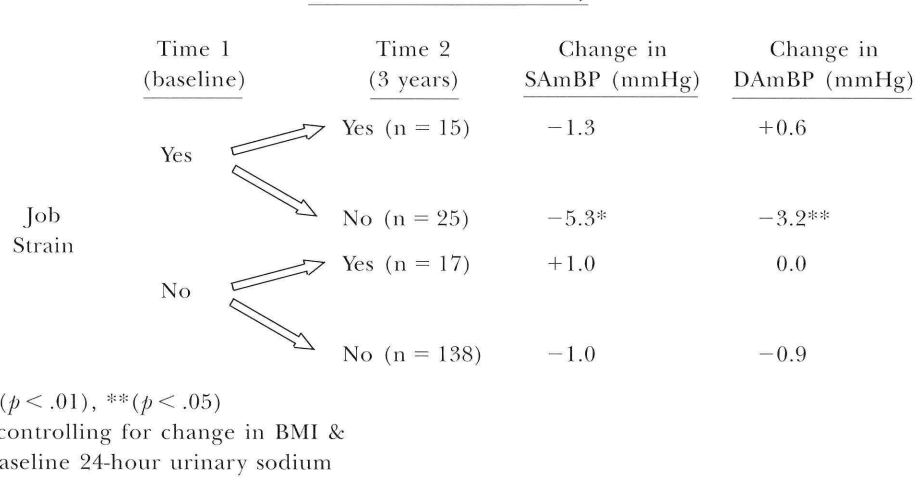

Fig. 2 Three Year Change in Mean Work Systolic & Diastolic Ambulatory BP

ipants. This ability to replicate results from one period to the next constitutes important additional evidence of an association between 'job strain' and AmBP[16]. The scientific significance of the findings from the cross-sectional replication is enhanced by the fact that there was a greater than 50% turnover rate in those individuals classified as having 'job strain'.

Those in high strain jobs at both Time 1 and Time 2, the 'chronic job strain' group, have much higher work and home AmBP (11–12 mmHg SAmBP and 6–9 mmHg DAmBP), than those not exposed to high strain at either assessment[15]. These group differences, more than one standard deviation in magnitude, are large by any standard[17]. By way of comparison, they are more than twice the difference between blacks and whites, and larger than the estimated effect of aging 25 years or gaining

50 pounds in weight. Although the chronic strain group is relatively small in size (8% of the sample), it identifies a subset of employed men who are substantially more likely to be hypertensive than the general population.

The longitudinal analysis provides mixed support for the relationship of 'job strain' to changes in AmBP at work and home. We entered this analysis with two hypotheses. The 'cumulative exposure hypothesis' predicted that those in the chronic high strain group would experience an increase in AmBP during the follow-up period, after controlling for aging and changes in weight. While this group already had substantially elevated AmBP at entry into the study, their blood pressure did not increase further during the subsequent three years. We suspect that this group had more consistent and chronic exposure to job strain before entry into the study, compared to those in the other three groups, and that this accounts for much of the elevation in their blood pressure. (A study of the early stages of people's careers would be helpful in elucidating how those in chronic high strain jobs come to have elevated AmBP.) However, the present data do not permit us to test this empirically, and therefore we cannot rule out alternative possibilities such as 1) a third factor that influences both blood pressure and job strain, 2) the self selection of those with high blood pressure into high strain jobs, or 3) a reporting bias, among those with high blood pressure, pertaining to psychological job demands and decision latitude. While theoretically plausible, none of these alternative explanations seems likely to us.

A second major hypothesis—the 'parallel changes hypothesis'—predicted that changes in 'job strain' would be associated with parallel changes in AmBP. This hypothesis was supported in one direction, but not the other. Those subjects with 'job strain' at Time 2 but not at Time 1 did not exhibit the predicted increase in AmBP, though their blood pressures were a little higher at both times than the group that was not exposed to 'job strain' at either assessment. However, those with 'job strain' at Time 1 but not at Time 2 had a significant decrease in ABP at work and home after controlling for other risk factors. Moreover the fall in work AmBP in the group exposed at Time 1 and not at Time 2 is largest (-11.3 mmHg systolic AmBP and -5.8 mmHg diastolic AmBP) among those subjects who entered the study as cases (i.e., subjects with elevated casual blood pressures at recruitment, $N = 10$). This finding suggests that the removal of 'job strain', especially for those with elevated blood pressure, can result in a substantial reduction in AmBP.

Two unexpected and interesting findings about job strain in our study are worth noting. First, is the observation that job characteristics (both demands and control) vary with time for a majority of the subjects in the study. A number of reasons exist for this finding:

Individual's change jobs
Individual's jobs change
Individuals' perceptions of their jobs change with time

Second, we find that employees reporting 'job strain' are not any more likely to report increased anxiety or other psychological symptomatology than those in non-strain jobs. This suggests the need for caution in interpreting reports of "stress" among working people, since the absence of such reports will not necessarily indicate that they are free of risk for 'job strain' and increased cardiovascular disease.

These results point up the importance of repeated measures of exposure in trying to assess the impact of job strain (or any chronic stressor) on physiological processes over time. Job strain is not like a demographic variable, which can be ascertained at baseline and assumed to be constant throughout the follow-up period. The evidence suggests that exposure/non exposure has strong and fairly immediate (within 1 year) effects on blood pressure. Thus failure to take into account changes in exposure over time will result in substantial misclassification error which will lead to serious underestimates of effects.

Taken together our findings support the following conclusions:

1. Job strain, age and BMI are the only variables in our study significantly related to AmBP both cross-sectionally and prospectively.
2. Job strain is a strong risk factor for hypertension in our study.
3. Job strain is associated with a generalized and persistent arousal beyond the imme-

diate work situation.

4. Decreases in job strain over time are related to significant decreases in awake AmBP.
5. There does not appear to be a consistent interaction between age and job strain, or between alcohol and job strain. A significant interaction was observed for each of these pair of variables at Time 1 but not at Time 2.
6. Repeated exposure to job strain is associated with markedly higher AmBP's relative to those without any exposure or those reporting exposure to job strain at only one point in time.

References

1) Schnall P, Landsbergis P, and Baker D : Job strain and cardiovascular disease. Ann Rev of Pub Health **15** : 381～411, 1994
2) Johnson J and Johannson G : The Psychosocial Work Environment: Work Organization, Democratization and Health. Amityville, NY, Baywood Publishing, 1991
3) Theorell T and Karasek R : Current issues relating to psychosocial job strain and cardiovascular disease research. J Occ Health Psych **1** : 9～26, 1996
4) Kasl SV : The influence of the work environment on cardiovascular health: A historical, conceptual, and methodological perspective. J Occ Health Psych **1** : 42～56, 1996
5) Schnall PL, Pieper C, Schwartz JE, Karasek RA, Schlussel Y, Devereux RB, Alderman M, Warren K, and Pickering TG : The relationship between 'job strain', workplace diastolic blood pressure, and left ventricular mass index. JAMA **263**(14) : 1929～1935, 1990
6) Schnall PL, Devereux RB, Pickering TG, and Schwartz JE : Letter to the Editor. The Relationship Between 'Job Strain,' Workplace Diastolic Blood Pressure, and Left Ventricular Mass Index: A Correction. JAMA **267**(9) : 1209, 1992
7) Schnall PL, Schwartz JE, Landsbergis P, Warren K, and Pickering TG : The relationship between job strain, alcohol, and ambulatory blood pressure. Hypertension **19**(5) : 488～494, 1992
8) James G, Yee L, Harshfield G, Blank S, and Pickering T : The influence of happiness, anger, and anxiety on the blood pressure of borderline hypertensives. Psychosomatic Med **48** : 502～508, 1986
9) Pickering TG : Ambulatory Monitoring and Blood Pressure Variability. London, Science Press, 1991
10) Llabre MM, Ironson GH, Spitzer SB, Gellman MD, Weidler DJ, and Schneiderman N : How many blood pressure measurements are enough?: An application of generalizability theory to the study of blood pressure reliability. Psychophysiology **25** : 97～106, 1988
11) Devereux R, Alonso D, Lutas E, Gottlieb G, Campo E, Sachs I, and Reichek N : Echocardiographic assessment of left ventricular hypertrophy: Comparison to necropsy findings. Am J Cardiol **57** : 450～458, 1986
12) Karasek R, Pieper C, Schwartz J, Fry L, and Schrier D : Job Content Instrument Questionnaire and Users Guide. New York, Columbia University Job/Heart Project, 1985
13) Karasek R, Theorell T, Schwartz J, Schnall P, Pieper C, and Michela J : Job characteristics in relation to the prevalence of myocardial infarction in the U.S. Health Examination Survey (HES) and the Health and Nutrition Survey (HANES). Am J Pub Health **78**(7) : 1～9, 1988
14) SAS Institute Inc.: SAS Technical Report P-229, SAS/STAT Software: Changes and enhancements, Release 6.07. Cary, NC, SAS Institute Inc., 1992
15) Schnall PL, Schwartz, JE, Landsbergis, PA, Warren K, and Pickering, TG : Longitudinal Study of Job Strain and Ambulatory Blood Pressure: Results from a 3-year Follow-up. Psychosomatic Medicine 60 : 697～706, 1998
16) Rothman KJ : Modern Epidemiology. Boston/Toronto, Little Brown and Company, 1986
17) Cohen J : Statistical Power Analysis for the Behavioral Sciences (revised edition). New York, Academic, 1977