

Variation in the ambulatory blood pressure response to daily work load — the moderating role of job control

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Objectives This quasi-experimental study tested the ambulatory blood pressure responsivity to daily variation in the work load of the same workers and examined whether this responsivity is moderated by perceived job control.

Methods The subjects were 79 nonshift, normotensive men who reported nearly almost equal occurrences of low and high work load in a typical workday. Job control was assessed by questionnaire. The workers recorded their situational work load and other parameters at each recording of ambulatory blood pressure.

Results An analysis of covariance showed the main effects of both situational work load and job control on systolic ambulatory blood pressure, as well as a significant work load by job control interaction, even after control for clinic blood pressure, age, and body mass index. A blood pressure response to increased work load was observed only for workers with low job control. These workers also had a higher average systolic ambulatory blood pressure than workers reporting high control. The difference was 6.2 mm Hg (0.82 kPa) during the low workload periods and 10.2 mm Hg (1.36 kPa) during the high workload periods. A further multiple regression analysis confirmed the interaction and the main effect of job control but not that of work load, after control for work-related activities, body position, and hour of examination.

Conclusions This study showed that ambulatory blood pressure at work can fluctuate with variations in work load but only for workers with low job control. Low job control is independently associated with higher systolic ambulatory blood pressure.

Key terms job strain, psychological, responsivity.

Work load is one of the major forms of job demand and has been suggested to be a possible risk factor in cardiovascular disease (1, 2). Many studies have examined the association between work load and blood pressure as a possible mechanism linking work load and cardiovascular diseases, but with inconsistent results (1). For example, Rose & Fogg (3), in a comprehensive study of air traffic controllers, found that varying work load was positively associated with systolic and diastolic blood pressure, heart rate, and cortisol level in some men, while in others no association, or even a negative association, was found. They suggested that some untested factors, such as differing task requirements or individual appraisals of increasing work loads, may explain the conflicting responses. We believe that another possible reason for the inconsistencies between work load and cardiovascular or

neuroendocrine responses in this and other studies is the failure to account for the potent moderating effect of decision latitude or job control.

Job control is a key component in the job-strain model of Karasek & Theorell (2). According to this model, stress-related disease risk is a product of the interaction of work load and job control. The greatest risk is imposed by a combination of high work load and low job control; however, the negative impact of high work load can be offset by high job control. Tasks composed of high work load and high control (active jobs) are considered positively stimulating and challenging and do not increase the risk of stress-related disease. Less elaborated in the job-strain model are the outcomes of the interplay between low work load and low or high job control. This model has prompted researchers to shift from testing the effect

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of work load or job control separately to examining the association between job strain (a product of work load and job control) and the risk factors of cardiovascular disease.

Several studies have investigated the association between job strain and blood pressure with blood pressure measured in a clinic setting in which typically only a few casual readings were taken. Only 2 showed a positive finding (4, 5). In recent years clinicians have begun to use ambulatory blood pressure, based on evidence that such measurements may be superior to conventional resting measurements in predicting cardiovascular risk (6–9). Of the 12 reported job strain studies utilizing ambulatory blood pressure, 7 showed a positive association (5, 10–15) and 5 showed no association or even a negative association (16–20). Nearly all of them contrasted 2 conditions, high and low job strain, with respect to their effect on ambulatory blood pressure. Only 2 studies (5, 15) tested the work load by job control interaction, and in one (15) the results were significant. Furthermore, work load was either inferred by the participants' job titles or determined by the overall workload score on the respective scale. In practice, however, work load can vary considerably throughout the workday and at the times when the ambulatory blood pressure was measured. It is not clear to what extent the measures used reflect actual workload levels. It is plausible that ambulatory blood pressure would covary more closely with the situational work load noted (in a diary) concurrently with the ambulatory measures. To the best of our knowledge, no one has tested the job-strain model with respect to ambulatory blood pressure responses during varying work loads in the workplace.

The present quasi-experimental study examined the response of ambulatory blood pressure to daily variation in work load (low versus high) in the same workers. We hypothesized that the response of ambulatory blood pressure to work load would be moderated by perceived job control.

Subjects and methods

Subjects

One hundred and eighty-five male nonshift workers employed in 6 industrial plants (light metal, chemical, electronics, and heavy metal industries) were asked to undergo ambulatory blood pressure monitoring as part of a hypertension screening program. Over 93% complied ($N=173$). Of these, 28 were excluded, 17 because they were being treated for hypertension, had clinic diastolic blood pressure values greater than 95 mm Hg (12.64 kPa), or were taking medication that might affect blood pressure and 11 because they had missing values in one or more of the study variables. Therefore 145 workers

remained; they were between 27 and 60 years of age (mean 44.1 years), with a mean education of 11.6 years and tenure of 1 to 40 years (mean 13.4 years).

Inspection of the distribution of the situational work load (see the description of the diary parameters) based on self-reports showed a considerable variation during the workday for the same workers. By and large, of the 3932 workload measurements taken, 68.2% had a low work load and only 31.8% had a high work load. To ensure an equal contribution of the study participants to the outcome and to create a quasi-experimental situation in which the same workers would be compared under conditions of low and high situational work load, only data of workers who had at least 5 measurements of both low and high workload were retained for subsequent analyses. The sample size therefore became 79. Of the 2105 measurements available for these workers, 48.1% had a low work load and 51.9% had a high work load.

Methods

The following 2 types of data were collected in a workday for each worker: ambulatory blood pressure measurements and a diary record of the concurrent situational work load and other parameters known to affect blood pressure. Prior to the field measurement, base-line blood pressure levels were measured at the plant clinic on the worksite. On a separate day, the workers completed a set of demographic, medical, and psychological (job control) questionnaires.

Blood pressure measurement

The clinic measurements were performed by a trained technician between 0700 and 0800, and the ambulatory monitoring was conducted on the same day between 0800 and 1600. To ensure comparability, all the blood pressure measurements were made with a portable monitor (Accutrack II, Suntech Medical Instruments, Raleigh, NC, USA). Before the measurements with the ambulatory blood pressure monitor, 3 blood pressure readings were taken with an ordinary sphygmomanometer after a 5-minute rest with the subject in the sitting position; these readings were not used in the analysis. Following an additional 5-minute rest, 3 resting blood pressure measurements were taken with the monitor while the subject was in the sitting position, and the average of the 3 was used in the analysis. For the ambulatory monitoring, the monitor was set to record blood pressure every 15 minutes. These readings were reviewed, and obvious artifacts were coded by the instrument (such as erratic or missing heart beats, weak or insufficient number of Korotkoff sounds), as well as systolic blood pressure outside the range of 70–200 mm Hg (9.31–26.60 kPa), and diastolic values

outside the range of 40–120 mm Hg (5.32–15.96 kPa) and values yielding a pulse pressure of less than 10 mm Hg (1.33 kPa) (constituting 1.1% of all the readings) were eliminated from the analysis. There was no loss of readings as a result of editing these artifacts. The monitor was programmed to repeat the measurement following each invalid reading. The average number of readings for each worker was 26.6.

Diary parameters

Work load was defined in terms of the amount of work to be done in the time available. It was scored on a 4-point scale, from 1 (low) to 4 (high). Based on the frequency distribution, scores 1 and 2 were considered low work load and scores 3 and 4 high work load.

In addition to work load, several other parameters known to influence ambulatory blood pressure (21) were noted: activities (regular work activities, eating, resting or bicycling), and body position (sitting, standing or walking). The workers recorded these parameters and the work-load score in a personal diary at the time of each blood pressure reading.

Job control

Job control was assessed by the 6-item perceived control scale described by Melamed et al (22). Each item is rated on a 6-point scale according to the perceived freedom to make decisions concerning the contents, method, and priority of the work. The items are "My opinions and suggestions influence what happens at work", "My job enables me to make decisions on my own and to follow them through", "I have sufficient authority to carry out everything my job requires", "I am free to determine how to perform my work", "My job enables me to participate in making decisions about work procedures and regulations", "My job enables me to influence the policy and goal setting of the place in which I work". Cronbach's alpha for this scale is 0.74. The median score on this scale was used to divide the subjects into high and low job-control groups.

Demographic and medical data

Other data gathered by the self-administered questionnaire were demographic information, medical history, awareness of cardiovascular problems including hypertension, and use of medication.

Data analysis

Possible differences in age, body mass index [BMI = weight (kg)/height (m²)], and clinic systolic and diastolic blood pressure between the workers with low and high job control and between these subgroups and the workers excluded from this study were tested with a 1-way analysis of variance (ANOVA).

The data on each worker's ambulatory blood pressure were reduced by separately averaging the readings recorded during the low and high workload situations. This procedure yielded 4 data points per worker: mean systolic and diastolic ambulatory blood pressure for low and high work load. The effect of variation in work load on systolic and diastolic ambulatory blood pressure for workers with low and high job control was tested by a 2-way analysis of covariance (ANCOVA): job control x work load (repeated measures), using the SAS general linear model procedure (23). Age and BMI were used as covariates. Also included as a covariate were base-line (clinic) blood pressure values. The inclusion of base-line values in the ANCOVA is equivalent to the analysis of residualized change from the base line. Statistical significance was defined as $P < 0.05$.

Results

The characteristics of the subjects, divided by low and high perceived job control, are given in table 1. No difference between these 2 subgroups was found in age, percentage of high workload reports and base-line systolic and diastolic blood pressure. The mean BMI was higher

Table 1. Characteristics of the final study sample (by job-control level) and the workers excluded. (SBP = systolic blood pressure, DBP = diastolic blood pressure, SE = standard error, BMI = body mass index)

Sample	N	Age (years)		BMI		High work load (%)	Job control score		Clinic SBP (mm Hg ^a)		Clinic DBP (mm Hg ^a)	
		Mean	SE	Mean	SE		Mean	SE	Mean	SE	Mean	SE
Low job control	42	44.2	1.4	25.3	0.7	48.1	28.3	1.0	131.4	2.6	78.4	1.8
High job control	37	44.4	1.5	27.6	0.8	51.9	40.1	1.6	124.5	2.7	75.3	2.0
Excluded workers	66	43.2	1.1	27.2	0.7	10.4	37.2	0.8	125.3	2.1	77.3	1.5
Test of significance	.	F(2,144)=0.26		F(2,144)=2.36		$\chi^2(2)=4.5$	F(2,144)=39.7		F(2,144)=2.16		F(2,144)=0.72	
P	.	0.772		0.098		0.001	0.0001		0.119		0.487	

^a 1 mm Hg $\approx$ 0.133 kPa.

for the workers with high job control ($P < 0.05$). The subjects excluded did not differ from the study subgroups in mean age, BMI, or clinic blood pressure. They had an intermediate level of job control and, expectedly, a low percentage of high work load.

The mean values of the systolic and diastolic ambulatory blood pressure in the low and high workload periods, separately for workers with low and high job control, are given in table 2. The results of the ANCOVA test showed the main effects of work load (a time effect) [$F(1,74)=5.37$, $P=0.023$] and job control [$F(1,74)=4.11$, $P=0.046$], as well as a work load by job control interaction [$F(1,74)=10.62$, $P=0.001$] on systolic ambulatory blood pressure. Inspection of the mean values in table 2 reveals clear support for the moderating effect of job control on the association of increased work load with systolic ambulatory blood pressure response. The systolic ambulatory blood pressure increased with increased situational work load, but only for workers who reported low job control. In contrast, there was no change in systolic ambulatory blood pressure in response to increased work load for those reporting high job control. Furthermore, a comparison of workers with low and high job control showed that the systolic ambulatory blood pressure in the former was higher by 6.2 mm Hg (0.82 kPa) during low situational work loads, and this difference increased to 10.2 mm Hg (1.36 kPa) during high situational work loads. No significant results were obtained for diastolic ambulatory blood pressure [$F(1,74)=0.18$, $P=0.67$; $F(1,74)=3.45$, $P=0.067$; $F(1,74)=0.35$, $P=0.55$, respectively].

Finally, we tested the possibility that the response of ambulatory blood pressure to variations in situational work load stems from certain confounders that are associated with both of these variables. We adopted the approach of James et al (24) and Melamed et al (25) in which all ambulatory readings serve as the basis for analysis. We used multiple linear regression analysis with ambulatory blood pressure as the dependent variable. The predictor variables were situational work load, job control, and their interaction. To avoid the risk of biasing the estimates of the interaction terms because of multicollinearity (26), the 2 predictor variables were centered. We controlled for base-line (clinic) blood pressure and work activities and body positions of the worker at the time of the blood pressure measurement. The contribution of work-related activities [normal work, bicycling (around the plant), taking a break, lunch] was tested against the base-line values; the contribution of body position (standing and walking) was tested against the sitting values. To account for the repeated measurements taken for each worker and a possible diurnal effect on blood pressure (27), the hour of examination (time in hours from start of measurements) was entered into the regression model.

The results indicated that, after control for several possible confounders, there was a significant main effect of

job control (regression coefficient $B=-1.69$, standardized $\beta=-0.10$, $P<0.0001$), as well as a significant work load by job control interaction ($B=-0.79$, $\beta=-0.05$, $P=0.012$), on systolic ambulatory blood pressure. No main effect of work load was observed ($B=0.05$, $\beta=0.00$, $P=0.86$). The intercept was 52.17 and the total R^2 was 0.371. Conducting the regression analysis in 2 separate runs indicated that the contribution of the confounder variables (work-related activities, body position, and hour of examination) to the total variance explained was minimal. The total R^2 without these variables was 0.365. When the interaction was plotted to facilitate understanding (figure 1), the same trend was noted as for the findings obtained when the ambulatory blood pressure readings for each worker were averaged across low and high workload situations. The only difference in the results of the 2 modes of the data

Table 2. Systolic and diastolic ambulatory blood pressure by situational work load for workers with low and high job control.

Job control	Ambulatory blood pressure			
	Systolic		Diastolic	
	Mean	SD	Mean	SD
Low (N=42)				
Low situational work load	135.7	16.3	80.1	8.3
High situational work load	139.9	17.5	80.2	9.0
High (n=37)				
Low situational work load	129.5	11.2	77.1	6.2
High situational work load	129.7	10.1	76.9	7.1

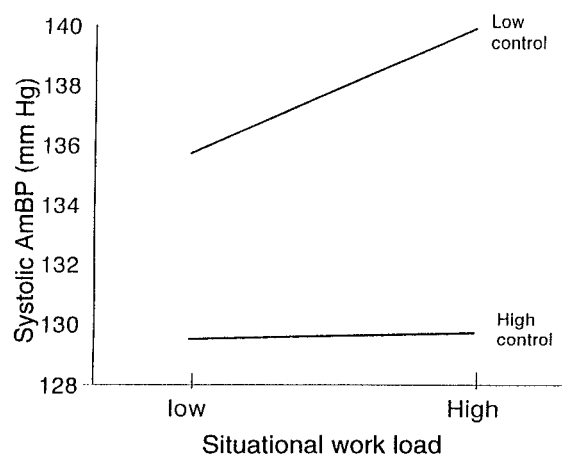


Figure 1. Average systolic ambulatory blood pressure (AmBP) by situational work load and job control. (1 mm Hg = 0.133 kPa)

analysis was that, in the regression analysis, no main effect of work load was disclosed.

No significant interactive effect of work load and job control on diastolic ambulatory blood pressure was found ($B=-0.41$, $\beta=-0.04$, $P=0.054$). On the other hand, a significant main effect of job control ($B=-0.58$, $\beta=-0.06$, $P=0.007$), but not of work load ($B=0.01$, $\beta=0.00$, $P=0.955$), was observed. The intercept was 43.75 and the total R^2 was 0.192. As before, the contribution of the possible confounders to the total R^2 explained was minimal ($\Delta R^2 = 0.01$). These results largely replicated the earlier ones with the averaged ambulatory blood pressure readings. However, a main effect of job control was observed in this study, whereas in the ANCOVA tests this effect was not significant.

Discussion

The findings of this quasi-experimental study of normotensive workers showed a significant situational work load by job control interaction on systolic ambulatory blood pressure ($P=0.001$), even after control for clinic systolic blood pressure and other possible confounders. A blood pressure response to increased work load was found only for workers with low job control; no such response was observed for workers with high job control. The former group had a higher systolic ambulatory blood pressure than the latter, the difference in the average value being 6.2 mm Hg (0.82 kPa) during a low situational work load and 10.2 mm Hg (1.36 kPa) during a high situational work load. Thus the important moderating effect of job control that was found may partly explain the inconsistencies in the association between variation in work load and cardiovascular responses encountered in earlier studies (1, 3), in which job control was not measured.

Our findings support the job-strain model of Karasek & Theorell (2). Of particular importance is the finding that the effect of increased work load is offset by the perception of control. As has already been mentioned, the moderating effect of job control is central to the job-strain model, but only 2 of the 12 earlier studies of job strain and ambulatory blood pressure have tested this effect, and one (15) confirmed it. Furthermore, the strength of the present study is in its rigorous testing of the job-strain model. We considered the actual work load at the time of the ambulatory blood pressure monitoring, rather than reports of work load in general or inferences from job titles, as done in previous other studies. This approach also enabled us to test the change in ambulatory blood pressure with increasing work load for the same workers, which increased sensitivity.

The full diary parameters enabled us to rule out the possibility that the results obtained were due to the influence of other factors. The results of the multiple

regression analysis applied to the data indicated that the work load by job control interaction on systolic ambulatory blood pressure was retained (see figure 1), even after control for 8 possible confounders, including base-line blood pressure values, work activities, and body position. Thus the effect of varying work load on systolic ambulatory blood pressure goes beyond the possible changes in body position and activities that may accompany changes in work load. This finding suggests that subjective work load is influenced more by the content of the task performed than by the physical activities entailed. It was further encouraging to note that the significant interactive effect of work load and job control on the outcome was obtained independently of the mode of statistical analysis.

Work load is generally considered to be a major contributor to blood pressure level. Indeed the ANCOVA results with systolic ambulatory blood pressure supported this contention. However, work load was not a significant predictor of this outcome in the linear regression model. This difference is probably due to the somewhat different way of testing the effect of work load. In the ANCOVA procedure, high and low workload conditions were treated as repeated measures (and tested as time effect), which was not the case in the regression analysis. In addition, the results of our study highlight the significance of perceived control. A significant main effect of job control on systolic ambulatory blood pressure was uncovered ($P=0.046$). Workers reporting high job control had lower values of systolic blood pressure at work than those with low control. A similar trend was also observed for the clinic systolic values (table 1), but the difference failed to attain statistical significance ($P=0.07$). The significance of job control to health has been discussed at length in the stress literature (28, 29). Yet many studies of ambulatory blood pressure at work have not examined the main effect of job control. Surprisingly, the 2 studies that did concern the main effect of job control found no association between job control and ambulatory blood pressure (15, 19). A possible reason for this discrepancy with our findings, besides the difference in design, is the difference in the conceptualization and measurement of perceived job control. In these studies, and also in many others, job control or decision latitude has been defined as a combination of skill, discretion, and decision authority. We defined job control as perceived freedom to make decisions concerning the content, method, and priority of work, which is conceptually similar to decision authority. At any rate, further studies are warranted to examine whether our positive findings can be replicated and whether job control alone or its interaction with work load attenuate blood pressure at work.

It was noteworthy that job strain, a product of situational work load and job control, was associated with systolic ambulatory blood pressure but not with diastolic

ambulatory blood pressure. This phenomenon may have been due mainly to the influence of the situational work load. Transient mental stress has been shown to affect systolic more than diastolic ambulatory blood pressure (7). At any rate, in the majority of the studies cited, the impact of job strain was more significant on systolic than diastolic ambulatory blood pressure. Another important advantage of this study was that the response of ambulatory blood pressure to job strain was obtained after control for the clinic blood pressure values. The change in ambulatory blood pressure (above the clinic blood pressure values) because of job strain has been demonstrated in only 1 previous study (17). The potential importance of ambulatory blood pressure responsivity can be inferred from recent evidence that ambulatory blood pressure has an additional prognostic value for cardiovascular risk in essential hypertension, over and above clinic blood pressure values (8, 9).

In conclusion, this study points out the efficacy of measuring the situational work load in investigations of the contribution of job strain to blood pressure levels at work. The average situational workload measures may provide a more valid estimate of the overall work load. Although many researchers rely on reported work load in general, there is no clear evidence indicating that job strain assessment based on reported work load in general is consistently related to ambulatory blood pressure. Furthermore, the generalizability (or external validity) of the reported overall work load may be further challenged by the observation of Theorell et al (19) of a substantial spontaneous variation in reported job strain over time. Further studies with both men and women are needed to examine how well the reported overall work load reflects the range in the situational work load in a given workday and to contrast the 2 measures of work load in predicting ambulatory blood pressure at work.

Another worthwhile complementary investigation would be to compare subjective work load with externally rated and objective indicators of work load in predicting ambulatory blood pressure responses. We found that subjective work load showed the expected association with blood pressure response, whereas Rose & Fogg (3) did not find such an association for air-traffic controllers using an objective indicator of work load (number of planes under control). Furthermore, Manenica (30), in a review of the relevant literature, argued that subjective work load is superior to ratings by an objective observer in predicting physiological responses. Further studies employing all 3 measures of work load may provide a more definitive answer.

Finally, this study demonstrated the contribution of job control to the reduction of blood pressure at work. Besides its significant moderating effect on the systolic ambulatory blood pressure response to variation in work load, high job control was found to be independently as-

sociated with lower systolic ambulatory blood pressure when compared with low job control. This finding is congruent with the significance to worker's health assigned by occupational health psychologists to interventions aimed at facilitating the perception of control at work.

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