Journal of Occupational Health Psychology
2003, Vol. 8, No. 2, 146–156

1076-8998/03/$12.00 DOI: 10.1037/1076-8998.8.2.146

Job Demands, Decisional Control, and Cardiovascular Responses

George D. Bishop, Hwee Chong Enkelmann, Eddie M. W. Tong, Yong Peng Why, and Siew Maan Diong
National University of Singapore

Jansen Ang and Majeed Khader
Singapore Police Force

The demand–control model for coronary heart disease was tested using ambulatory blood pressure monitoring. Male patrol officers ($N = 118$) wore ambulatory blood pressure monitors during 1 of their day shifts with readings taken every 30 min. Following each reading, officers completed a questionnaire using a handheld computer. Significant interactions were obtained between job demands and decisional control for heart rate and pressure rate product such that both variables were highest under conditions of high demand and low control. Main effects were obtained for control such that diastolic blood pressure and mean arterial pressure were significantly higher under conditions of low control. These results support the demand–control model and emphasize the importance of psychological control in cardiovascular responses.

Since it was proposed in the 1970s by Karasek (1979), the demand–control model of occupational stress has received a great deal of attention, particularly as it relates to health. Karasek argued that mental strain on the job results from a combination of heavy job demands and low levels of decision latitude and in turn leads to negative health effects. While the combination of high demand and low decision latitude is hypothesized to result in high strain on the job, low demand combined with high decision latitude is expected to produce low strain whereas low demand combined with low decision latitude produces a "passive" job and high demand in conjunction with high decision latitude results in an "active" job. Only the high demand–low decision latitude combination is considered to be harmful to health.

Research on the demand–control model as it relates to physical and mental health has produced mixed results. On the one hand, a number of studies have found evidence for the model with respect to mental health (de Jonge, Dollard, Dormann, Le Blanc, & Houtman, 2000; Mausner-Dorsch & Eaton, 2000; Wall, Jackson, Mullarkey, & Parker, 1996), general physical health (Parkes, Mendham, & von Rabenau, 1994; Sacker, Bartley, Frith, Fitzpatrick, & Marmot, 2001), immune functioning (Meijman, van Dormolen, Herber, Rongen, & Kuiper, 1995), blood pressure (BP) levels (Fox, Dwyer, & Ganster, 1993; Landsbergis, Schnall, Schwartz, Warren, & Pickering, 1995; O'Connor, O'Connor, White, & Bundred, 2000; Van Egeren, 1992), hypertension (Landsbergis et al., 1995), angina pectoris (Netterstrom, Kristensen, Moller, Jensen, & Schnohr, 2001), coronary heart disease (CHD; Alfredsson & Theorell, 1983; Sacker et al., 2001), and risk factors for CHD (Tsutsumi et al., 1995). On the other hand, a number of studies have either not obtained the predicted interaction between demand and control or have found the interaction to be very small (Brown & James, 2000; de Rijk, Le Blanc, Schaufeli, & de Jonge, 1998; Fletcher & Jones, 1993; Friedman et al., 2001; Landsbergis, 1988; Schreurs & Taris, 1998; Wamala, Mittleman, Horsten, Schenck-Gustafsson, & Orth-Gomer, 2000).

Operationalizations of demand and control have varied from study to study with the definition in some studies being based on overall job characteristics as rated externally (Netterstrom & Sjol, 1991; Rad-

George D. Bishop, Hwee Chong Enkelmann, Eddie M. W. Tong, Yong Peng Why, and Siew Maan Diong, Department of Social Work and Psychology, National University of Singapore, Singapore; Jansen Ang and Majeed Khader, Police Psychological Unit, Singapore Police Force, Singapore.

Eddie M. W. Tong is now at the Department of Psychology, University of Michigan. Yong Peng Why is now at the Department of Psychology, St. Andrews University, St. Andrews, Scotland. Siew Maan Diong is now at the Police Psychological Unit, Singapore Police Force.

This research was funded by Grant R-107-000-007-112 from the National University of Singapore Academic Research Fund with supplemental funds from the Singapore Police Force, Ministry of Home Affairs. Portions of this research were presented at the Society of Behavioral Medicine's 23rd Annual Meeting, Washington, DC, April 5, 2002.

Correspondence concerning this article should be addressed to George D. Bishop, Department of Social Work and Psychology, National University of Singapore, 11 Law Link, Singapore 17570. E-mail: swkgb@nus.edu.sg

macher & Sheridan, 1995; Theorell et al., 1991) and in others by job characteristics as rated by the participants themselves (de Jonge et al., 2000; Netterstrom et al., 2001; Sacker et al., 2001). In these studies the dependent variables have been overall measures of health status, symptoms, or risk factors. These studies examine the hypothesis that overall job strain affects health over the long term.

A third way of investigating demand and control is to examine variations within the same job over time using what has been termed *ecological momentary assessment* (EMA). One mechanism through which demands and control may have their effects is through the person's physiological responses to recurring events in daily life. Even though the overall level of strain that a person experiences over time may be related to health outcomes, it seems likely that this overall strain results from the accumulation of individual events. As such, studying momentary experience of demand and control provides a more proximal measure of these variables that should be more sensitive to variations over time. Although momentary events can be studied retrospectively, for example, by asking about stressful events that the person has recently experienced, such approaches are likely to suffer from recall bias and can only tap the effects of such events in a general way. EMA has the advantage of potentially capturing information on spontaneously occurring events and their physiological concomitants as they happen, thus reducing recall bias and increasing precision of measurement. In addition, within-subjects approaches such as EMA provide control for individual differences by examining relationships as they occur across time within the same individuals. Further discussion of EMA and its methodological advantages can be found in Stone and Shiffman (1994). When applied to the demand–control model, this approach can examine the effects of momentary job demands and control as they influence BP or other time-varying measures. Only a few studies have used a within-subjects design to study job demands over time (Hockey, Payne, & Rick, 1996; Payne & Rick, 1986). The results of the only study to date which has used this approach to explicitly examine the predicted interaction between demand and control on cardiovascular responses were not supportive of the model. Kamarck and his colleagues (Kamarck, Shiffman, et al., 1998) monitored the BP and heart rate (HR) of 120 healthy adults over a 6-day period using ambulatory blood pressure (ABP) monitoring. Each time BP and HR were obtained, the participants were to answer a computerized questionnaire concerning their activities, emotional state, and task strain, among other variables. Following adjustment for covariates such as posture, activity, talking, and caffeine consumption, decision control was found to be significantly negatively related to diastolic blood pressure (DBP) and marginally and negatively related to systolic blood pressure (SBP) and HR. Task demand was related marginally and positively to HR but not to SBP or DBP. A significant interaction was obtained between demand and control for HR, with HR showing a negative relationship with control under conditions of low demand but no relationship under high demand.

The present study was undertaken as part of a larger study of stress among Singapore police officers that included examination of overall stress and coping and their relationship to personality (Bishop et al., 2001) as well as both laboratory and ambulatory monitoring of cardiovascular responses (Why et al., 2003). As part of the ambulatory monitoring, officers had their BP and HR taken at approximately 30-min intervals during one of their morning shifts. After each measurement they answered a computerized questionnaire asking about their activities as well as perceptions of job demands and decisional control. HR and BP are important measures of cardiovascular functioning with epidemiological significance for heart disease (Brownley, Hurwitz, & Schneiderman, 2000). SBP measures the peak pressure during a given cardiac cycle, with DBP measuring the lowest pressure. Mean arterial pressure (MAP) measures the average pressure exerted on arteries, whereas pressure rate product (PRP $=$ HR $\times$ SBP, in mmHg/min) is considered to be an estimate of myocardial oxygen demand. These measures were chosen as indicators of cardiovascular reactivity as previous research has shown evidence that they are associated with progression of atherosclerosis as well as the development of CHD (Kamarck, Everson, et al., 1998; Manuck, 1994). The demand–control model predicts that there will be an interaction between demand and control such that the impact on health measures will be greatest under conditions of high demand and low control. Thus we expected to find a significant interaction between demand and control such that each of the dependent variables would be highest in situations of high demand and low control.

Method

Participants

Participants in this research were 118 police patrol officers from the Singapore Police Force, ranging in age from

19 to 50 years. Of these, 10 were eliminated from the sample because of equipment failure (5), baseline readings suggesting hypertension (3), or having been transferred to nonpatrol duties (2). Demographics for the remaining 108 officers are shown in Table 1.

Equipment

ABP assessment. BP and HR readings were obtained using Accutracker II BP monitors (Suntech Medical Instruments, Inc., Raleigh, NC). The Accutracker II is a portable (350 g) automated BP monitor that uses the ascultatory method. A microphone is fastened over the brachial artery of the nondominant arm for the detection of Korotkoff sounds. Three standard electrocardiographic electrodes are attached to the chest so that the Accutracker II can monitor the participant's cardiac cycle for the purpose of reducing artifactual readings due to movement of the participant (Pollak & Obrist, 1983; White, Schulman, McCabe, & Nardone, 1987). This procedure minimizes the interference from artifactual sounds, such as sounds from body movement and mechanical vibrations, allowing accurate readings to be taken even when participants are in motion, a critical concern in an ambulatory study with police officers. The Accutracker II has been validated against sphygnomanometry and intra-arterial BP (White, Lund-Johansen, McCabe, & Omvik, 1989). Following the general recommendation of Pickering (1991), the deflation rate was set at 3 mmHg per second. BP readings were initiated at 30-min intervals with a random fluctuation of 5 min to avoid officers anticipating readings and altering their behavior as a result. In the event of erroneous readings detected by the monitor, a repeat reading was automatically initiated 4 min later.

Table 1
Sample Demographics

Variable	*n*	%
Race		
Chinese	36	33.3
Malay	31	28.7
Indian	41	38.0
Age[a]	26.85 (5.15)	
BMI[a]	22.95 (0.27)	
Marital status		
Married	39	36.1
Single	68	63.0
Separated/divorced	1	0.9
Religion		
Free thinker	6	5.7
Buddhist/Taoist	29	27.4
Christian	4	3.8
Muslim	45	42.5
Hindu	22	20.8
Monthly family income		
Under $1,500	13	12.0
$1,500–2,499	30	27.8
$2,500–3,499	29	26.9
$3,500–4,499	22	20.4
$4,500 and above	14	13.0

[a] Numbers for age and body mass index (BMI) are means with standard deviations in parentheses.

Electronic diary. Data concerning job demands and decisional control as well as time-varying covariates for analyses of ABP data were obtained using a questionnaire programmed into a Palm IIIx handheld computer (3Com Corp., Santa Clara, CA) using Pendragon Forms (Pendragon Software Corp., Libertyville, IL). The Palm IIIx is small, light, and portable, making it easy and convenient for the officers to carry while they were on duty. Officers wore a custom-made carrying case, containing the Accutracker II and the Palm IIIx, attached to the belt. By having diary entries made electronically on the Palm IIIx, it was possible to time and date stamp all entries, thus ensuring that officers completed diaries in a timely fashion and allowing for an accurate determination of diary compliance.

Measures

Covariate items were concerned with collecting information about variables that may confound ambulatory cardiovascular readings. Ten potential covariates, including physical activity, standing, sitting, hot, cold, talking, smoking, caffeine, meal, and body mass index (BMI) were selected on the basis of their likely effects on HR and BP and their use in previous research (see Kamarck, Shiffman, et al., 1998). The items and response scales used are shown in Table 2. For variables with a yes/no response, no was coded as 0 and yes as 1. Because temperature and posture are categorical variables and thus not suitable for entry into regression analysis, they were recoded as binary variables for use as covariates. For temperature, two variables were derived: hot (0 = *comfortable or too cold*, 1 = *too hot*) and cold (0 = *comfortable or too hot*, 1 = *too cold*).[1] Similarly, for posture, the covariates of standing (0 = *lying down, sitting*, 1 = *standing, walking/running*) and sitting (0 = *lying down, walking/running, standing*, 1 = *sitting*) were derived by comparing each posture with other possible postures. Physical activity was measured on a 4-point scale from 1 (*inactive*) to 4 (*strenuous activity*).

To assess job demand, we asked officers if they were required to be working hard in the 10 min prior to the BP measurement and whether they were required to juggle several tasks at once. Officers were asked to respond to both items using a 4-point scale ranging from 1 (*not at all*) to 4 (*very much so*). Similarly, decisional control was measured using two items in which officers were asked if they could choose to do something different now if they wanted to and whether they could choose to do what they are doing now at a different time. Responses to these items were made using the same response scales as for the job demand items.

To verify the structure of these four items, we computed pooled within-participant correlations between the items and then subjected the results to principal-components anal-

[1] The variables for hot and cold are coded as separate binary variables rather than as a 3-point scale (too cold, comfortable, too hot) because there is no evidence that the 3 points on the latter scale are equally spaced and fulfil the assumptions of interval measurement. As such, the more defensible approach is to use binary dummy coding for the purposes of entering them as covariates.

Table 2
Control Items Used in the Diary

Item	Response option
Posture	Walking/running
	Standing
	Sitting
	Lying down
Temperature	Comfortable
	Too hot
	Too cold
Talking?	Yes/no
Taken a meal?	Yes/no
Consumed caffeine?	Yes/no
Smoked?	Yes/no
Consumed medication/drugs?	Yes/no
Describe physical activity	Inactive—doing nothing
	Some movement—casual walk
	Moderate—walk quickly
	Strenuous—running, exercising

ysis. Two components with eigenvalues of 1.69 and 1.58 were obtained. Varimax rotation of these components indicated, as expected, that the two items concerned with decisional control loaded onto one factor with loadings of .92 (able to choose to do what they are doing now at a different time) and .91 (can choose to do something different now), whereas the two job demand items loaded onto the other factor with loadings of .89 for both items. As such the two items for each component were summed to obtain the measures of decisional control and job demand, respectively. To check the correlation between these measures, we computed within-subject correlations between the measures of decisional control and job demands across observations for each participant, which were then transformed using Fisher's Z and averaged. The average correlation across participants was –.12, indicating that the two measures were effectively independent.

Procedure

Because the officers in this study worked rotating shifts following a specified pattern, the ambulatory monitoring was always done during a morning shift at the same point in each officer's shift rotation schedule. Officers were met at 7 a.m. by members of the research team and fitted with the BP monitor. After being fitted with the monitor, test runs were made to ensure that the equipment was operating properly, following which the officers sat quietly for 10 min before two sitting baselines were taken, with the second reading activated immediately after the first one was completed. Therefore, the interval between baselines readings was about 1 min. After the sitting baselines were taken, officers stood up for 2 min before two standing baseline readings were obtained, again at an interval of approximately 1 min.

After the baseline HR and BP readings were taken, officers were familiarized with the use of the electronic diary. They were first asked to read a set of instructions describing the diary and its use. They then made a trial run with the guidance of a research team member. The trial run was to clarify any queries from the officers and to ensure that they understood the questions in the electronic diary and the use of the handheld computer. Officers were told to take the deflation of the BP cuff as a cue to make a diary entry. This way officers did not have to remember the time intervals and did not have to carry other equipment, such as a pager, to be reminded to do the questionnaire. Officers were also instructed to take out the electronic diary only after the completion of the BP reading. This was to minimize the potential for erroneous BP measurements due to arm movements. Taped underneath the cover of the palmtop computer was a set of written instructions along with contact numbers of research team members, in case the participant encountered any problems.

The morning shift ended at 3 p.m., but officers were encouraged to continue wearing the monitor after shift hours so as to obtain additional readings. Only a few officers had prior engagements and left promptly at 3 p.m. Most of the officers met the members of the research team again between 4 and 6 p.m. At the end of the ambulatory recording period, the procedure used in the morning for obtaining baseline readings was repeated, after which the equipment was detached from the officer.

Data Cleaning and Matching

Erroneous readings. The criteria outlined by Marler, Jacob, Lehoczky, and Shapiro (1988) were used to eliminate erroneous BP and HR readings. Both SBP and DBP values were excluded from analyses if SBP $>$ 250 mmHg or $<$ 70 mmHg, DBP $>$ 150 mmHg or $<$ 45 mmHg, or SBP/DBP $>$ 3 or $<$ [1.065 + (.00125 * DBP)]. HRs above 200 beats per minute (bpm) or below 40 bpm were also excluded from analyses. In addition, error codes generated by the Accutracker II were inspected to identify other readings that should be eliminated because of weak Korotkoff sounds, microphone difficulties, and other mechanical problems.

Data matching. Because both diary entries and ABP readings were time and date stamped, it was possible to accurately match each diary entry with its corresponding ABP reading. A maximum of 10 min difference between the diary entry and the ABP reading was allowed for a match to be made. Lags in the timing of diary entries were expected because police officers might well be preoccupied with work at the time of the ABP reading. In cases in which repeat ABP readings were taken due to problems with the initial reading, the repeat measurement was matched to the diary entry triggered by the erroneous reading provided that the time between the ABP reading and the diary entry was not more than 10 min.

Data Quality

During the ambulatory monitoring 2,401 readings were attempted on the final sample of 108 officers. Out of these, 1,758 (73.2%) were valid and 643 (26.8%) were erroneous or artifactual. Also, 1,335 diary entries were collected from the 108 patrol officers. Altogether the final data set contained 1,895 observation periods or an average of 17.5 observation periods for each participant. Out of these 1,895 observation periods, there were 1,733 (91.5%) valid BP readings and 162 (8.5%) missing readings. In addition, there were 1,208 diary entries (63.7% of observation periods), out of which 1,128 (93.4%) could be matched to BP readings. Overall, it was possible to match diary entries to 65.1% of the valid BP readings. Tests of differences between match and unmatched readings indicated only small differences between them. The only significant difference was found for HR, in which unmatched HR readings were slightly higher than matched ones ($M = 80.5$ vs. 79.0), $F(1, 83) = 5.68$, $p = .0195$. Comparisons for the other dependent variables did not approach significance.

Compliance was determined by the percentage of matched diary entries to the number of valid ABP readings taken during the entire monitoring period. Out of the 108 officers, 78 (72.2%) provided at least 50% matched diary entries, whereas another 13 provided a minimum of six matched diary entries, which was set as the minimum number of matched entries for inclusion in data analyses.

Statistical Analysis

The use of multilevel random-coefficients regression has been recommended for analyzing EMA data (Schwartz & Stone, 1998). PROC MIXED (Littell, Milliken, Stroup, & Wolfinger, 1996) was used for the statistical analyses. PROC MIXED is a generalization of the general linear model and can handle unbalanced data that are unavoidable in an ambulatory study. A study such as this one has unbalanced data due to missing diary entries, invalid BP readings, different number of observations for each participant, and different situations encountered in the observations.

Both between- and within-subject effects can be evaluated in a PROC MIXED analysis. In this case the between-subjects effects included BMI as a control variable and the mean values for job demand and decisional control for each participant, whereas the within-subject effects were the time-varying experiences of job demand and decisional control along with the covariates of physical activity, posture, hot, cold, talking, smoking, caffeine consumption, and having eaten a meal obtained from the diary. Because the raw scores of momentary rating of job demand and decisional control contain unknown between-subjects effects, within-person measures of these variables were obtained by taking each participant's average for the given variable across all diaries and subtracting this mean from the individual observations (Schwartz & Stone, 1998). These person-centered measures were then multiplied to obtain their interaction. Analysis then proceeded by first entering the covariates along with the person means for job demand and control followed by the person-centered job demand and decisional control measures with their interaction entered last. Testing of the error covariance structure using Akaike's Information Criterion (Akaike, 1987) indicated that a combination of autoregressive order one and compound symmetry was optimal. Restricted maximum likelihood was used for estimating the parameters of the model.

Results

Covariate Selection

As noted earlier, potential covariates were selected on the basis of their likely influence on ABP and HR readings and use in previous research. To select the final variables to be used as covariates in the analyses of the ambulatory data and eliminate covariates having no relationship with the dependent variables in this sample, we first carried out separate random effects regression analyses on each potential covariate. Because endorsement of the item for consumption of medication was very infrequent, this variable was excluded as a covariate. The dependent variables SBP, DBP, HR, MAP, and PRP were analyzed separately. Each potential covariate was tested individually against each dependent variable. Those potential covariates showing a significant bivariate relationship with at least one dependent variable were retained for later use. Feeling too cold and consumption of caffeine had no significant effects on any of the dependent variables. As a result, they were not included in the later analyses. Combined analyses including all eight remaining covariates were then carried out for each dependent variable. Means and standard deviations of all variables are given in Table 3.

Main Analyses[2]

Results of the main analyses are given in Table 4. The key prediction of the job demand–control model is an interaction between job demands and decisional control such that the strongest physiological reactions are expected in situations involving high demand and low control. Tests of the Demand × Control interaction produced significant effects for both HR, $F(1, 881) = 5.08$, $p = .0245$, and PRP, $F(1, 881) = 6.22$, $p = .0128$. As can be seen in Figures 1 and 2, these interactions showed the predicted pattern with both HR and PRP elevated under conditions of high demand and low control. In addition, a similar interaction was obtained for SBP and MAP, but these interactions did not reach convention levels of statistical significance, $F(1, 881) = 2.66$, $p = .1029$ and $F(1, 881) = 2.45$, $p = .1176$, for SBP and MAP, respectively. Although the predicted interaction was not

[2] To ascertain whether race moderated the results, we ran preliminary analyses including race and its interactions in the model. As no significant interactions involving race were found, race was dropped from the analysis model.

Table 3
Means and Standard Deviations for Covariates, Independent Variables, and Dependent Variables

Variable	*M*	*SD*
Physical activity in the last 10 min?[a]	0.95	0.63
Standing?[b]	0.31	0.46
Sitting?[b]	0.66	0.47
Hot?[b]	0.13	0.33
Talking?[b]	0.65	0.48
Smoke?[b]	0.11	0.31
Eaten something?[b]	0.24	0.43
Body mass index	22.95	2.86
Job demands (person mean)[c]	3.52	0.98
Decisional control (person mean)[c]	4.47	1.15
Job demands (time varying)[d]	−0.01	1.17
Decisional control (time varying)[d]	0.00	1.55
Systolic blood pressure	123.39	14.08
Diastolic blood pressure	73.56	11.10
Heart rate	79.19	13.82
Mean arterial pressure	89.84	10.65
Pressure rate product	9.80	2.22

[a] Scaled from 1 (*inactive*) to 4 (*strenuous*).
[b] Scaled 0 (*no*) and 1 (*yes*).
[c] Scaled from 2 to 8.
[d] Represents deviation from person mean.

obtained for DBP, significant effects were obtained for control such that DBP decreased with increasing levels of control, $b = -0.55$, $t(881) = -2.60$, $p = .0095$. This same effect was obtained for MAP, $b = -0.47$, $t(881) = -2.47$, $p = .0137$. Also a significant effect was obtained for mean level of decisional control such that individuals reporting a higher level of average decisional control during the diary period had lower DBP, $b = -1.16$, $t(84) = -2.08$, $p = .0403$. No other statistically significant results were obtained from the analyses.

Discussion

On the whole the results of this study are consistent with the job demand–control model. As predicted, HR and PRP were significantly higher under conditions of high demand–low control and the effect for SBP and MAP were in the predicted direction although not statistically significant. Although the demand–control interaction was not found for DBP, a significant effect was obtained for decisional control such that DBP was lower with greater feelings of control. Relatedly, this effect was also obtained for MAP.

To date, evidence supporting the demand–control model as it relates to BP and hypertension has been almost entirely concerned with the cumulative effects of demand and control over time. For example, the Cornell Work-Site Study (Landsbergis et al., 1995; Schnall, Schwartz, Landsbergis, Warren, & Pickering, 1998) followed nearly 200 employed men over a 3-year period using ABP monitoring to obtain average HR and BP measures both during the day and at night. The results of this study showed that, both at the beginning of the study and 3 years later, men reporting job strain showed higher BP than those not reporting strain. In addition, those in high-strain jobs at the beginning of the study but not 3 years later showed a decrease in ABP. These results illustrate the cumulative effects of job strain as well as the beneficial effects of reducing job strain.

The results obtained in the present study point to the effects on HR and BP of momentary demands and control. In the context of this study, the demands and control primarily had to do with routine tasks that officers were involved in at the police station or while on patrol. Examination of responses to the diary question about location indicated that the officers were at the police station or neighborhood police post during 64% of the diary entries and on patrol or in their vehicle for an additional 25% of the entries. Singapore officers face situations of extreme danger relatively infrequently, and it is likely that the de-

Table 4
Regression Analyses

Effect	*df*	Systolic blood pressure		Diastolic blood pressure		Heart rate		Mean arterial pressure		Pressure rate product	
		b (*SE*)	*t*	*b* (*SE*)	*t*	*b* (*SE*)	*t*	*b* (*SE*)	*t*	*b* (*SE*)	*t*
Covariates											
Intercept	84	103.55 (7.89)	13.13***	57.09 (5.37)	10.63***	70.03 (8.61)	8.14***	72.36 (5.60)	12.93***	7.22 (1.32)	5.45***
Physical activity	881	−0.01 (0.74)	−0.02	0.37 (0.61)	0.60	2.53 (0.61)	4.13***	0.19 (0.56)	0.34	0.29 (0.10)	2.88*
Standing	881	2.17 (2.47)	0.88	−2.11 (2.08)	−1.01	4.94 (2.03)	2.44*	−0.79 (1.91)	−0.41	0.78 (0.34)	2.31*
Sitting	881	−0.66 (2.39)	−0.28	−2.90 (2.01)	−1.44	0.61 (1.96)	0.31	−2.24 (1.85)	−1.21	−0.01 (0.32)	−0.02
Feeling hot	881	3.18 (1.33)	2.38*	3.14 (1.11)	2.83**	5.28 (1.12)	4.71***	3.19 (1.02)	3.12**	0.95 (0.19)	5.10***
Talking	881	1.79 (0.86)	2.07*	1.27 (0.72)	1.75	0.49 (0.72)	0.68	1.44 (0.67)	2.16*	0.17 (0.12)	1.43
Smoking	881	1.35 (1.42)	0.95	1.59 (1.18)	1.35	2.60 (1.18)	2.21*	1.57 (1.09)	1.44	0.49 (0.19)	2.50*
Eating or having a meal	881	0.79 (0.95)	0.83	0.41 (0.80)	0.52	1.23 (0.79)	1.55	0.57 (0.73)	0.78	0.24 (0.13)	1.83
Body mass index	84	0.76 (0.32)	2.35*	0.72 (0.21)	3.42**	0.01 (0.36)	0.01	0.74 (0.23)	3.27**	0.06 (0.06)	1.05
Independent variables											
Demand (person average)	84	−0.29 (0.99)	0.77	0.10 (0.65)	0.16	−0.06 (1.11)	−0.06	−0.03 (0.69)	−0.04	−0.04 (0.17)	−0.23
Control (person average)	84	−0.87 (0.87)	−1.00	−1.15 (0.56)	−2.08*	−0.87 (0.97)	−0.90	−1.06 (0.60)	−1.77	−0.19 (0.15)	−1.25
Demand (time varying)	881	0.16 (0.37)	0.44	0.38 (0.31)	1.22	0.45 (0.31)	1.45	0.33 (0.28)	1.15	0.08 (0.05)	1.47
Control (time varying)	881	−0.32 (0.25)	−1.26	−0.55 (0.21)	−2.60**	−0.18 (0.21)	−0.85	−0.47 (0.19)	−2.47*	−0.05 (0.03)	−1.50
Demand × Control (time varying)	881	−0.30 (0.19)	−1.63	−0.21 (0.15)	−1.34	−0.35 (0.16)	−2.25*	−0.22 (0.14)	−1.57	−0.06 (0.03)	−2.49*

* $p < .05$. ** $p < .01$. *** $p < .001$.

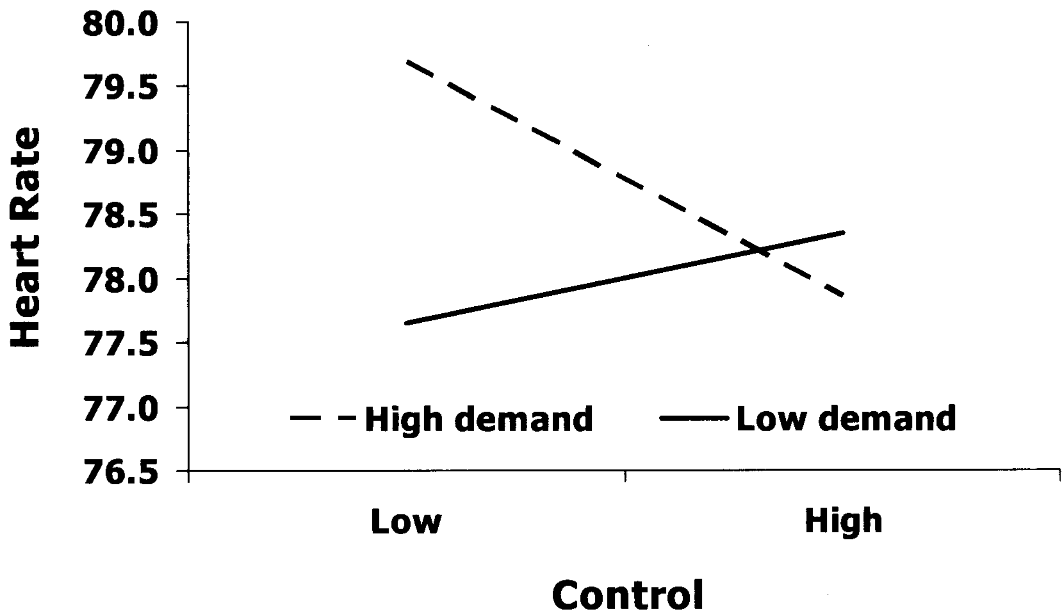

Figure 1. Demand × Control interaction for heart rate. High and low job demands and decisional control are defined as being scores of +1 *SD* and –1 *SD,* respectively, on the measure in question.

mands had to do primarily with administrative tasks at the station, dealing with complainants, patrolling the streets, and other routine police duties. Because the questions used to assess demand were concerned with how hard the person was working and whether he was required to juggle several tasks at once, demand in this context was a reflection of workload at the time of the diary entry. The questions used to assess decisional control emphasized the ability of the officers to make choices as to the tasks that they were undertaking at any particular time and whether they could reschedule what they were currently doing at another time if they wanted to.

Presumably the long-term effects of job strain come from the accumulation of the effects of momentary strains as they mount up over time. Research evidence suggests an association between psychophysiological reactivity and cardiovascular risk (Kamarck, Everson, et al., 1998; Manuck, 1994), risk that may come from endothelial damage, atherogenesis, or some other process leading to increased CHD risk. Thus the fact that situations of high job demand and low decisional control lead to increased cardiovascular reactivity suggests that the cumulative effects of job strain may well have their impact at least partially through physiological reactivity.

The question naturally comes up as to the reasons for the discrepancy between the results obtained in this study and those obtained by Kamarck, Shiffman, et al. (1998). To the best of our knowledge, the study by Kamarck and his colleagues is the only other published study examining the effects of high demand–low control on momentary cardiovascular responses. Although they found a significant interaction between task demands and decisional control, the shape of the interaction was not in accord with the demand–control model. Instead of higher levels of control moderating the impact of high job demands, decision control was related only to HR under conditions of low job demand. At this point we can only speculate on the reasons for the differences between the results of the two studies. One possibility is the nature of the sample. The sample in the Kamarck, Shiffman, et al. study was an American one with relatively equal representation among Black men, Black women, White men, and White women who were employed in a variety of occupations. By contrast, the sample in the present study was comprised entirely of Asian male police officers, with relatively equal representation from Chinese, Malays, and Indians. Previous studies have shown that the effects of job strain appear to be most prominent among males

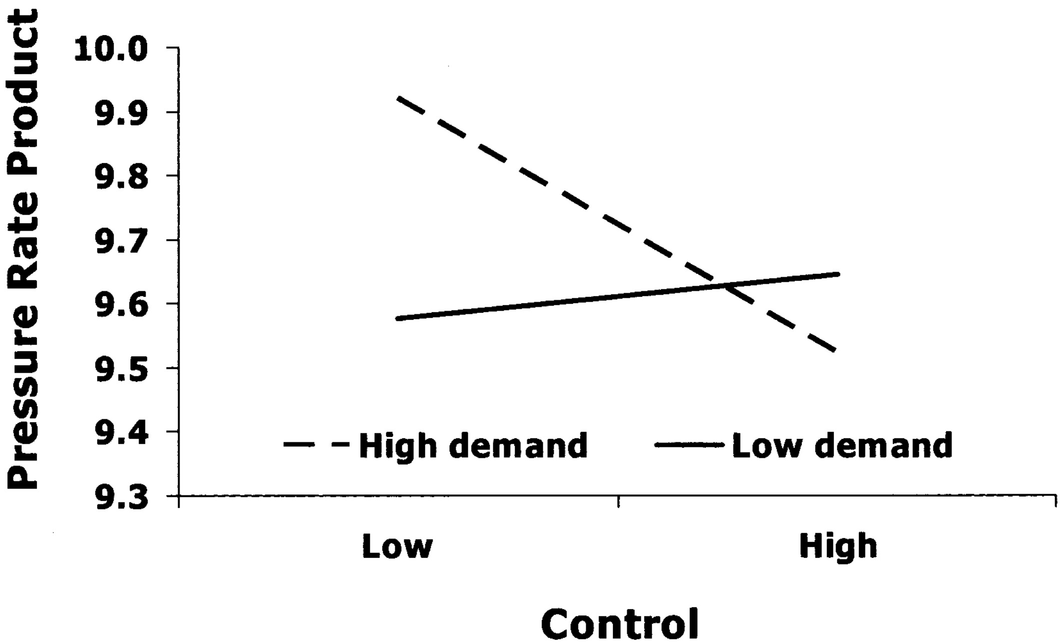

Figure 2. Demand × Control interaction for pressure rate product. High and low job demands and decisional control are defined as being scores of +1 *SD* and –1 *SD,* respectively, on the measure in question.

(Brown & James, 2000; Pickering et al., 1996; Wamala et al., 2000). Thus the fact that our sample was entirely male may have been one of the reasons for the difference in outcomes. Also, this is the first study of its kind in an Asian population, and it is possible that this may have contributed to the difference. Another difference is that the present study controlled for BMI and smoking, two covariates that showed significant relationships with the dependent variables in this study, whereas Kamarck, Shiffman, et al.'s study did not control for these. Regardless of the reasons, the differences in outcome strongly indicate the need for replicating the results obtained.

When interpreting the results of this study, it is important to keep in mind its limitations. As noted, the sample was entirely male and comprised only of police patrol officers. Although we would expect the same results to be obtained from other occupational groups, this remains an empirical question for future research. Also the dataset was a relatively small one with a final effective sample of 91 officers monitored at 30-min intervals over a period of up to 10 hr. A larger dataset would have definitely been desirable. Also there were problems with cooperation with the diary, leading to the fact that we were able to use only 65% of the valid ABP readings with diary entries. This is very likely the result of the difficulty encountered by officers in completing the diary during their patrol duties. Because times of high job strain are precisely the times when it is most difficult to do the diary, it would appear quite likely that our estimates of the effects of demand and control on BP and HR are an underestimate. In future, research efforts need to be made to increase cooperation through reducing the burden of the diary or other means.

Finally, the measures taken of job demands and decisional control were generic self-reports of the extent to which the person was required to work hard and juggle tasks (for job demand) or could choose to do current tasks at a different time or choose different tasks at the current time (for decisional control). As such it is not possible to know exactly what kinds of situations were perceived as being high demand–low control, high demand–high control, and so on. Future research should include measures such as postmonitoring interviews to obtain information on how different situations are defined on these dimensions.

In conclusion, the results of this study show support for the job demand–control model. However, a number of questions remain, such as whether these findings are specific to males only as well as whether the same results would be found with other ethnic and occupational samples.

References

Akaike, H. (1987). Factor analysis and Akaike Information Criterion. *Psychometrika, 52,* 317–332.

Alfredsson, L., & Theorell, T. (1983). Job characteristics of occupations and myocardial infarction: Effects of possible confounding factors. *Social Science & Medicine, 17,* 1497–1503.

Bishop, G. D., Tong, E. M. W., Diong, S. -M., Enkelmann, H. C., Why, Y. P., Khader, M., & Ang, J. C. H. (2001). The relationship between coping and personality among police officers in Singapore. *Journal of Research in Personality, 35,* 353–374.

Brown, D. E., & James, G. D. (2000). Physiological stress responses in Filipino-American immigrant nurses: The effects of residence time, life-style, and job strain. *Psychosomatic Medicine, 62,* 394–400.

Brownley, K. A., Hurwitz, B. E., & Schneiderman, N. (2000). Cardiovascular psychophysiology. In J. T. Cacioppo, L. G. Tassinary, & G. G. Berntson (Eds.), *Handbook of psychophysiology* (pp. 224–284). New York: Cambridge University Press.

de Jonge, J., Dollard, M. F., Dormann, C., Le Blanc, P. M., & Houtman, I. L. D. (2000). The demand–control model: Specific demands, specific control, and well-defined groups. *International Journal of Stress Management, 7,* 269–287.

de Rijk, A. E., Le Blanc, P. M., Schaufeli, W. B., & de Jonge, J. (1998). Active coping and need for control as moderators of the job demand–control model: Effects on burnout. *Journal of Occupational and Organizational Psychology, 71,* 1–18.

Fletcher, B. C., & Jones, F. (1993). A refutation of Karasek's demand-discretion model of occupation stress with a range of dependent measures. *Journal of Organizational Behavior, 14,* 319–330.

Fox, M. L., Dwyer, D. J., & Ganster, D. C. (1993). Effects of stressful job demands and control on physiological and attitudinal outcomes in a hospital setting. *Academy of Management Journal, 36,* 289–318.

Friedman, R., Schwartz, J. E., Schnall, P. L., Landsbergis, P. A., Pieper, C., Gerin, W., & Pickering, T. G. (2001). Psychological variables in hypertension: Relationship to casual or ambulatory blood pressure in men. *Psychosomatic Medicine, 63,* 19–31.

Hockey, G. R. J., Payne, R. L., & Rick, J. T. (1996). Intra-individual patterns of hormonal and affective adaptation to work demands: An $n = 2$ study of junior doctors. *Biological Psychology, 42,* 393–411.

Kamarck, T. W., Everson, S. A., Kaplan, G. A., Manuck, S. B., Jennings, J. R., Salonen, R., et al. (1998). Exaggerated blood pressure responses during mental stress are associated with enhanced carotid atherosclerosis in middle-aged Finnish man: Findings from the Kuopio Ischemis Heart Disease Study. *Circulation, 96,* 3842–3848.

Kamarck, T. W., Shiffman, S. M., Smithline, L., Goodie, J. L., Paty, J. A., Gnys, M., & Jong, J. Y. K. (1998). Effects of task strain, social conflict, and emotional activation on ambulatory cardiovascular activity: Daily life consequences of recurring stress in a multiethnic adult sample. *Health Psychology, 17,* 17–29.

Karasek, R. A. (1979). Job demands, job decision latitude, and mental strain: Implications for job redesign. *Administrative Science Quarterly, 24,* 285–308.

Landsbergis, P. A. (1988). Occupational stress among health care workers: A test of the job demands–control model. *Journal of Organizational Behavior, 9,* 217–239.

Landsbergis, P. A., Schnall, P. L., Schwartz, J. E., Warren, K., & Pickering, T. G. (1995). Job strain, hypertension, and cardiovascular disease: Empirical evidence, methodological issues, and recommendations for future research. In S. L. Sauter & L. R. Murphy (Eds.), *Organizational risk factors for job stress* (pp. 97–112). Washington, DC: American Psychological Association.

Littell, R. C., Milliken, G. A., Stroup, W. W., & Wolfinger, R. D. (1996). *SAS system for mixed models.* Cary, NC: SAS Institute.

Manuck, S. B. (1994). Cardiovascular reactivity in cardiovascular disease: "Once more unto the breach." *International Journal of Behavioral Medicine, 1,* 4–31.

Marler, M. R., Jacob, R. G., Lehoczky, J. P., & Shapiro, A. P. (1988). The statistical analysis of treatment effects in 24-hour ambulatory blood pressure recordings. *Statistics in Medicine, 6,* 697–716.

Mausner-Dorsch, H., & Eaton, W. W. (2000). Psychosocial work environment and depression: Epidemiologic assessment of the demand–control model. *American Journal of Public Health, 90,* 1765–1770.

Meijman, T. F., van Dormolen, M., Herber, R. F. M., Rongen, H., & Kuiper, S. (1995). Job strain, neuroendocrine activation, and immune status. In S. L.Sauter & L. R. Murphy (Eds.), *Organizational risk factors for job stress* (pp. 113–126). Washington, DC: American Psychological Association.

Netterstrom, B., Kristensen, T. S., Moller, L., Jensen, G., & Schnohr, P. (2001). Angina pectoris, job strain, and social status: A cross-sectional study of employed urban citizens. *International Journal of Behavioral Medicine, 5,* 312–322.

Netterstrom, B., & Sjol, A. (1991). Glycated haemoglobin (HbA1C) as an indicator of job strain. *Stress Medicine, 7,* 113–118.

O'Connor, D. B., O'Connor, R. C., White, B. L., & Bundred, P. E. (2000). Job strain and ambulatory blood pressure in British general practitioners: A preliminary study. *Psychology, Health and Medicine, 5,* 241–250.

Parkes, K. R., Mendham, C. A., & von Rabenau, C. (1994). Social support and the demand-discretion model of job stress: Tests of additive and interactive effects in two samples. *Journal of Vocational Behavior, 44,* 91–113.

Payne, R. L., & Rick, J. T. (1986). Heart rate as an indicator of stress in surgeons and anaethetists. *Journal of Psychosomatic Research, 30,* 411–420.

Pickering, T. G. (1991). *Ambulatory monitoring and blood pressure variability.* London: Science Press.

Pickering, T. G., Devereux, R. B., James, G. D., Gerin, W., Landsbergis, P., Schnall, P. L., & Schwartz, J. E. (1996). Environmental influences on blood pressure and the role of job strain. *Journal of Hypertension, 14*(Suppl.), S179–S185.

Pollak, M. H., & Obrist, P. A. (1983). Aortic-radial pulse transit time and ECG Q-wave to radial pulse wave interval as indices of beat-by-beat blood pressure change. *Psychophysiology, 20,* 21–28.

Radmacher, S. A., & Sheridan, C. L. (1995). An investigation of the demand–control model of job strain. In S. L. Sauter & L. R. Murphy (Eds.), *Organizational risk factors for job stress* (pp. 127–138). Washington, DC: American Psychological Association.

Sacker, A., Bartley, M. J., Frith, D., Fitzpatrick, R. M., & Marmot, M. G. (2001). The relationship between job strain and coronary heart disease: Evidence from the English sample of the working male population. *Psychological Medicine, 31,* 279–290.

Schnall, P. L., Schwartz, J. E., Landsbergis, P. A., Warren, K., & Pickering, T. G. (1998). A longitudinal study of job strain and ambulatory blood pressure: Results from a three-year follow-up. *Psychosomatic Medicine, 60,* 697–706.

Schreurs, P. J. G., & Taris, T. W. (1998). Construct validity of the demand–control model: A double cross-validation approach. *Work & Stress, 12,* 66–84.

Schwartz, J. E., & Stone, A. A. (1998). Strategies for analyzing ecological momentary assessment data. *Health Psychology, 17,* 6–16.

Stone, A. A., & Shiffman, S. S. (1994). Ecological momentary assessment (EMA) in behavioral medicine. *Annals of Behavioral Medicine, 16,* 199–202.

Theorell, T., deFaire, U., Johnson, J., Hall, E., Perski, A., & Steward, W. (1991). Job strain and ambulatory blood pressure profiles. *Scandinavian Journal of Work, Environment and Health, 17,* 380–385.

Tsutsumi, A., Tsutsumi, K., Kayaba, K., Theorell, T., Nago, N., Kario, K., & Igarashi, M. (1995). Job strain and biological coronary risk factors: A cross-sectional study of male and female workers in a Japanese rural district. *International Journal of Behavioral Medicine, 5,* 295–311.

Van Egeren, L. F. (1992). The relationship between job strain and blood pressure at work, at home, and during sleep. *Psychosomatic Medicine, 54,* 337–343.

Wall, T. D., Jackson, P. R., Mullarkey, S., & Parker, S. K. (1996). The demands–control model of job strain: A more specific test. *Journal of Occupational and Organizational Psychology, 69,* 153–166.

Wamala, S. P., Mittleman, M. A., Horsten, M., Schenck-Gustafsson, K., & Orth-Gomer, K. (2000). Job stress and the occupational gradient in coronary heart disease risk in women: The Stockholm Female Coronary Risk Study. *Social Science and Medicine, 51,* 481–489.

White, W. B., Lund-Johansen, P., McCabe, E. J., & Omvik, P. (1989). Clinical evaluation of the Accutracker II ambulatory blood pressure monitor: Assessment of performance in two countries and comparison with sphygmomanometry and intra-arterial blood pressure at rest and during exercise. *Journal of Hypertension, 7,* 967–975.

White, W. B., Schulman, P., McCabe, E. J., & Nardone, M. B. (1987). Clinical validation of the accutracker, a novel ambulatory blood pressure monitor using R-wave gating for Korotkoff sounds. *Journal of Clinical Hypertension, 3,* 500–509.

Why, Y. P., Bishop, G. D., Tong, E. M. W., Enkelmann, H. C., Diong, S.-M., Ang, J. C. H., & Khader, M. (2003). *Cardiovascular reactivity of Singaporean males as a function of task, ethnicity and hostility.* Manuscript submitted for publication.

Received February 15, 2002
Revision received November 7, 2002
Accepted November 23, 2002 ■