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The effect of job strain on nighttime blood pressure dipping among men and women with high blood pressure

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Objective Blunted nighttime blood pressure dipping is an established cardiovascular risk factor. This study examined the effect of job strain on nighttime blood pressure dipping among men and women with high blood pressure.

Methods The sample consisted of 122 blue- and white-collar workers (men=72, women=50). The Job Content Questionnaire was used to measure job psychological demands, job control, and social support. The ratio of job demands to job control was used to assess job strain. Nighttime blood pressure dipping was evaluated from 24-hour ambulatory blood pressure monitoring performed on three workdays.

Results Men with high job strain had a 5.4 mm Hg higher sleep systolic blood pressure (P=0.03) and 3.5 mm Hg higher sleep pulse pressure (P=0.02) compared to men with low job strain. Men with high job strain had a smaller fall in systolic blood pressure and pulse pressure from awake to sleep state than those with low job strain (P<0.05). Hierarchical analyses showed that job strain was an independent determinant of systolic blood pressure dipping (P=0.03) among men after adjusting for ethnicity, body mass index, anxiety and depression symptoms, current smoking status, and alcohol consumption. Further exploratory analyses indicated that job control was the salient component of job strain associated with blood pressure dipping (P=0.03).

Conclusions High job strain is associated with a blunting of the normal diurnal variation in blood pressure and pulse pressure, which may contribute to the relationship between job strain and cardiovascular disease.

Key terms ambulatory blood pressure; cardiovascular disease; diurnal variation; hypertension; pulse pressure.

Growing evidence indicates that job strain is an independent risk factor for hypertension (1–4). In terms of the etiology of hypertension, job strain is conceived as a chronic stressor that contributes to a progressive rise in blood pressure (BP). Using ambulatory blood pressure monitoring (ABPM), employees with high job strain have been observed to have higher BP at home and during sleep, as well as at work (5–10). The relationship of work stress and high ambulatory blood pressure (ABP) has been documented utilizing the demand–control or effort–reward imbalance model, which are the two contemporary approaches to assessing work related stress (11). Job strain was associated with elevated BP during sleep, implying the possibility that job strain may impact the circadian rhythm of BP (5). A blunting of the normal diurnal BP variation, or "non-dipping" of nighttime BP, is a risk factor for cardiovascular disease. A number of studies have reported that hypertensive patients with a non-dipping BP pattern (<10% fall in nighttime BP) show more end-organ damage and higher cardiovascular morbidity and mortality than those who show normal BP dipping (>10% fall in nighttime BP) (12, 13). However, there are few studies that have explored the relationship between job strain and blunted nighttime BP dipping (14, 15). The present study was designed to evaluate the impact of job strain on nighttime BP dipping in a study sample of untreated men and women with high normal or mildly elevated BP. In addition, gender was examined as a potential moderator of the effects of job strain on nighttime BP dipping because previous studies have shown that job strain tends to elevate BP among men rather than women (1, 16–18).

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Methods

Study design and participants

This report provides a secondary analysis of a study designed to explore the causes and consequences of nighttime BP dipping. Participants were recruited from newspaper, television advertisements, and posting of study brochures in hypertension clinics and primary healthcare offices in the hospitals of piedmont region of North Carolina. Advertisements and brochures sought volunteers with high blood pressure to participate in a research study of 24-hour ABPM. No information about the plan to evaluate job strain was mentioned prior to enrollment. Volunteers were eligible to participate if they were between 30–60 years old, had a regular job, had a systolic blood pressure (SBP) level between 130–159 mm Hg and diastolic blood pressure (DBP) level between 85–99 mm Hg [which includes the 7th report of the Joint National Committee on Prevention, Detection, Evaluation, and Treatment of High Blood Pressure (JNC 7) criteria (19) for stage 1 hypertension and the upper half of the pre-hypertension range]. Subjects were excluded if they had a body mass index (BMI) >35 kg/m^2, a history of antihypertensive medication usage, drug abuse in the previous 12 months, diabetes mellitus, or coronary heart disease. The process of participant selection included three clinic BP measurements and health history screening.

Of 598 people screened, 129 people met the BP eligibility criteria based on the average of 3 clinic BP readings and physical examination; 7 participants were excluded due to incomplete 24-hour ABP assessments. The remaining 122 subjects (72 men, 50 women) were included in the present analyses. Participants' occupations ranged from white- to blue-collar including professor, manager, educational consultant, educational analyst, teacher, physician, nurse, director, inspector, statistician, financial advisor, social worker, business owner, server/waitress, drivers, sales, cook/dish washer, housekeeper, and courier. Among all subjects, there were eight rotating shift workers (workday: day shifts; weekend: night shifts) and three night-shift workers. The Institutional Review Board at Duke University Medical Center approved the study. All eligible individuals provided written informed consent prior to participation.

Job strain measurement

Derived from the demand–control model (20), the Job Content Questionnaire was used to measure job strain. Participants completed this questionnaire after they had met all eligibility criteria and had been enrolled into the study. This 49-item scale yields measures of job psychological demands, job control (or decision latitude) and job-related social support. Job demands were measured by five items including working fast, working hard, excessive work, time constraints, and conflicting demands. Job control was defined as the sum of two subscales given equal weight: (i) skill discretion measured by six items (learning new things, creativity requirement, skill development, skill requirement, task variety, repetition) and (ii) decision authority measured by three items (freedom to make decisions, choice of ways to perform work, influence over job requirements). Social support consisted of both supervisor and coworker support. All questions were scored on a 4-point Likert scale, and job psychological demands and job control were constructed to have a range of 12–48. Job strain was evaluated by the ratio of job psychological demands divided by job control (21). A ratio >1.00 was regarded as high job strain, and a ratio ≤1.00 was regarded as low job strain.

24-hour ambulatory blood pressure monitoring

24-hour ABPM was conducted on three separate occasions during regular weekdays with an interval of one week between monitoring sessions. The Suntech Oscar II (Suntech Medical Inc, Raleigh, NC, USA) was utilized and programmed to record ABP every 20 minutes during waking hours and every 30 minutes during the sleep-period. The average awake and sleep BP in each ABPM occasion were computed through waking and sleep times defined by self-report and confirmed by actigraphy (see below).

Physical activity

Wrist actigraphy (Mini-Mitter Actiwatch 64, Mini Mitter, Bend, OR, USA) was worn during the same 24-hour ABPM period and used to derive total wake and sleep time, time in bed, and assess daytime physical activity (22). The actigraph recorded cumulative activity on a minute-by-minute basis. Waking physical activity was derived as the mean physical activity per minute (in arbitrary units) multiplied by the total number of waking minutes during the day.

Related psychosocial factors measurements

Depressive symptoms were assessed by the Beck Depression Inventory (BDI-II), which is a 21-item self-report scale (23). BDI-II depressive symptoms score can range from 0–63.

The Spielberger Trait Anxiety Inventory (STAI) was used to evaluate trait anxiety. This scale includes 20 self-report items (24). The trait anxiety score can range from 20–80.

Sample demographics

Participants' demographic information was collected through self-report questionnaires including age, gender, marital status, ethnicity, occupation, work schedule, work time, educational level, recent one year personal income, smoking status, alcohol consumption, and family history.

Statistical analysis

BDI-II and trait anxiety scores were trimmed at the 95th percentile in order to prevent excessive influence of outliers. Student's t-tests and Chi-square tests were used to compare the characteristics among subgroups defined by job strain and gender, among subgroups defined by two psychological dimensions and gender. Paired t-tests were used to test for within-group differences between awake and sleep averages of BP and pulse pressure (PP). In our study, diurnal variation in BP was evaluated by: (i) BP dipping defined as the difference between mean awake and sleep BP; and (ii) PP dipping defined as the difference between mean awake and sleep PP. Analysis of covariance (ANCOVA) was used to assess differences between awake and sleep averages of BP and PP among subgroups by two psychosocial dimensions and gender, and among subgroups by job strain and gender; awake SBP, awake DBP, BMI, physical activity, shift work, and BDI-II and trait anxiety scores were included as covariates, where appropriate. Hierarchical regression analyses were used to evaluate the association between diurnal SBP and job strain, and explore the association between diurnal SBP and job strain's component effects (job demands and control), while accounting for ethnicity, BMI, BDI-II score, trait anxiety score, current smoking status, and alcohol consumption. We explored the association of the job strain component dimensions of job demands and control with participant characteristics and ABP by contrasting these component scores in terms of tertiles. Data were analyzed by using SAS 9.2 (SAS Institute, Cary, NC, USA) with significance set at $P<0.05$.

Results

The psychosocial characteristics of subgroups by job strain and gender are shown in table 1. Twenty participants (11 men and 9 women) were classified as having high job strain; 61 men and 41 women had low job strain. The high job strain group was not significantly different from the low job strain group in screening BP, BMI, education level, the proportion of stage 1 hypertension, shift worker, ethnicity, income, current smoking status, and alcohol consumption. However, men with high job strain were younger [39, standard deviation (SD) 7.8 years versus 46, SD 8.3, years, $P=0.02$], were less likely to be married (27.3% versus 72.1%, $P=0.01$), and had higher BDI-II and trait anxiety scores ($P<0.01$) compared to men with low job strain. Both men and women with high job strain were characterized not only by higher job demands and lower job control, but also by lower coworker support and supervisor support compared to those with low job strain. Among tertile groups of job demands, men with high job demands were younger and had higher BDI-II and trait anxiety scores compared to men with low job demands ($P<0.05$). No difference of participants' characteristics was found among tertile groups of job control among men.

The average awake and sleep BP and PP of the high and low job strain groups are shown in table 2. As expected, BP and PP during sleep were lower than that BP and PP during waking hours ($P<0.01$), with the exception of high job strain men, in which the PP during sleep was not different from PP during the day ($P=0.87$). There was a significant job strain by gender interaction for SBP dipping ($P=0.01$). Post-hoc analysis of covariance revealed that men with high job strain had a 5.4 mm Hg higher sleep SBP ($P=0.03$) and 3.5 mm Hg higher sleep PP ($P=0.02$) compared to men with low job strain, after controlling for covariates. Men with high job strain showed a smaller fall in SBP ($P=0.03$) and PP ($P=0.04$) from the awake to sleep state compared to men with low job strain. No difference was found between the high and low job strain women.

The association of diurnal variation in BP with tertile groups of job demands, and job control among men is shown in table 3. As predicted, the diurnal variations of SBP, DBP, and PP between the awake to sleep state were related ($P<0.01$), with the exception of the high job demands and low job control groups, in which the PP during sleep was not different from PP during the day ($P>0.05$). An association between job control and diurnal variation in BP was found after controlling for covariates. Men with low job control had a 5.2 mm Hg higher sleep SBP ($P<0.01$) and a 2.8 mm Hg higher sleep PP ($P<0.01$) compared to men with high job control. Men with low job control showed a smaller drop in SBP (14.8 mm Hg versus 20.1 mm Hg, $P<0.01$) and PP (1.2 mm Hg versus 3.8 mm Hg, $P=0.01$) from the awake to sleep state compared to men with high job control. No difference was found among tertile groups of job demands and control among women.

Hierarchical regression analyses showed that job strain was a significant and independent determinant of SBP dipping among men (table 4). Men with high job strain had a 5.5 mm Hg ($P=0.03$) smaller fall in SBP from day to night compared to those with low job strain. Additional hierarchical regression analyses were conducted to explore the contribution of job strain's component factors,

Table 1. Sample psychosocial characteristics by gender and job strain group [BDI-II=Beck Depression Inventory; NS=not significant (P≥0.05); SD=standard deviation.]

Psychosocial characteristics	Men				P-value	Women				P-value
	Low strain (N=61)		High strain (N=11)			Low strain (N=41)		High strain (N=9)		
	Mean	SD	Mean	SD		Mean	SD	Mean	SD	
Job demand	29.3	5.2	35.8	5.5	<0.01	29.8	6.4	36.4	4.3	<0.01
Job control	37.9	6.4	27.3	6.0	<0.01	38.7	5.6	28.3	3.6	<0.01
Co-worker support	6.0	1.1	4.8	1.4	<0.01	6.2	1.1	5.0	1.3	<0.01
Supervisor support	11.6	2.5	9.6	2.4	0.019	12.4	2.3	9.9	2.4	<0.01
BDI-II total score	4.3	4.7	9.6	6.4	<0.01	5.0	5.45	6.11	6.4	NS
Trait anxiety score	32.6	7.1	39.3	8.3	<0.01	33.3	8.1	36.3	7.1	NS

Table 2. Mean and standard error (SE) for ambulatory blood pressure (ABP) and pulse pressure by gender and job strain group.

	Men				P-value [a]	Women				P-value [a]
	Low strain (N=61)		High strain (N=11)			Low strain (N=41)		High strain (N=9)		
	Mean	SE	Mean	SE		Mean	SE	Mean	SE	
Systolic ABP (mm Hg)										
Awake	136.9	1.2	136.4	3.0	0.885	134.2	1.6	138.3	3.6	0.304
Sleep [b]	117.9	0.9	123.3	2.2	0.026	117.8	0.8	115.5	1.9	0.289
Awake–sleep	18.8	0.9	13.4	2.2	0.026	17.1	0.7	19.4	1.8	0.289
Diastolic ABP (mm Hg)										
Awake	84.5	0.9	81.7	2.3	0.279	82.7	1.4	83.9	3.2	0.747
Sleep [b]	68.1	0.6	70.5	1.6	0.166	68.9	0.6	66.8	1.5	0.230
Awake–sleep	16.0	0.6	13.6	1.6	0.166	14.0	0.7	16.1	1.6	0.230
Pulse pressure (mm Hg)										
Awake	52.4	0.6	54.8	1.5	0.143	51.7	0.9	53.2	2.2	0.518
Sleep	49.8 [b]	0.5	53.3	1.3	0.018	48.8 [b]	0.4	49.1 [b]	1.0	0.787
Awake–sleep	2.9	0.6	-0.2	1.4	0.044	3.1	0.5	3.2	1.2	0.937

[a] Analysis of covariance among subgroups adjusted for awake ABP, body mass index, physical activity, shift work, depressive symptoms [Beck Depression Inventory (BDI-II score)] and trait anxiety score.
[b] Paired t-test for comparing awake and sleep ABP and pulse pressure among within-group, means are significantly >0 (P<0.01).

Table 3. Average ambulatory blood pressure (ABP) and pulse pressure (PP) by tertile groups of job demands and job control [a] (men=72).

	N	Systolic ABP (mm Hg)			Diastolic ABP (mm Hg)			Pulse pressure (mm Hg)		
		Awake	Sleep [b]	Awake-Sleep	Awake	Sleep [b]	Awake-Sleep	Awake	Sleep	Awake-Sleep
Job demands										
Low	22	138.3	118.1	18.7	85.2	68.5	15.6	52.4	49.7 [b]	3.0
Middle	27	134.6	118.7	18.1	82.4	68.5	15.5	53.2	50.2 [b]	2.7
High	23	137.9	119.5	17.2	84.9	68.3	15.7	52.5	51.1	1.5
Job control										
High	20	135.9	116.7	20.1	84.3	67.6	16.4	52.0	48.8 [b]	3.8
Middle	29	137.1	117.8	19.0	83.8	67.5	16.5	53.2	50.5 [b]	2.4
Low	23	137.1	121.9 [c]	14.8 [c]	84.1	70.4	13.7	52.9	51.6 [c]	1.2 [c]

[a] Analysis of covariance among subgroups adjusted for awake ABP, body mass index, physical activity, shift work, depressive symptoms [Beck Depression Inventory (BDI-II score)], and trait anxiety score.
[b] Paired t-test for comparing awake and sleep ABP and pulse pressure among within-group, means are significantly >0 (P<0.01).
[c] Means are significantly different from high job control group (P<0.05).

Table 4. Hierarchical regression models evaluating the association of systolic blood pressure dipping with job strain [a] (men=72). [BDI-II=Beck Depression Inventory; BMI=body mass index.]

	B	ß	P-value
Step 1 [b]			
Job strain group	-4.77	-0.25	0.038
Step 2 [b]			
Job strain group	-5.53	-0.28	0.028
Ethnicity	-1.54	-0.10	0.424
BMI	-0.32	-0.15	0.221
BDI-II Total score	-0.16	-0.14	0.374
Trait anxiety score	0.15	0.19	0.231
Current smoking status	-3.64	-0.16	0.169
Alcohol consumption	3.03	0.15	0.211

[a] Adjusted for ethnicity, BMI, depressive symptoms (BDI-II score), trait anxiety score, current smoking status, alcohol consumption.
[b] Adjusted R^2=0.047 for step1; adjusted R^2=0.124 for step 2.

Table 5. Hierarchical regression models evaluating the association of systolic blood pressure dipping with main effects and job strain (men=72). [BDI-II=Beck Depression Inventory; BMI=body mass index.]

	B	ß	P-value
Step 1 [a]			
Ethnicity	-2.65	-0.17	0.171
BMI	-0.27	-0.12	0.326
BDI-II Total score	-0.18	-0.16	0.326
Trait anxiety score	0.08	0.10	0.534
Current smoking status	-3.30	-0.15	0.225
Alcohol consumption	2.04	0.10	0.404
Step 2 [b]			
Job demands	-0.88	-0.10	0.429
Job control	2.35	0.26	0.029
Step 3 [c]			
Job demands	-0.35	-0.04	0.772
Job control	1.54	0.17	0.228
Job strain	-3.51	-0.18	0.261

[a] Included covariates; adjusted R^2=0.149.
[b] Main effects (job demands and job control) were added; adjusted R^2=0.214.
[c] Job strain was added; adjusted R^2=0.229.

job control and demands (table 5). After controlling for relevant covariates associated with SBP dipping (step 1), job control showed a significant and positive association with SBP dipping in the second step. However, when job strain was added to the model in a third step, neither job control nor job strain was significantly related to SBP dipping; this effect is likely a consequence of the overlapping characteristics of job strain and control.

Discussion

The average difference between waking and sleeping SBP or DBP is 10–20% among the normotensive population (25). Several studies (12, 13, 26, 27) have shown that blunted nighttime BP dipping, or non-dipping, is associated with end-organ damage, increased risk of future cardiovascular events, and higher cardiovascular morbidity and mortality. One recent Belgian study (14) suggested that job strain is an independent risk factor for non-dipping. Our study supports this possibility by demonstrating that men with high job strain had significantly blunted SBP and PP dipping compared to men with low job strain. We also found that circadian PP was attenuated among men characterized by high job strain. This observation appeared to reflect the impact of job strain on elevated SBP during sleep rather than during daytime hours. A similar observation is evident in a longitudinal study (7) in which job strain was related to elevations in SBP during the day as well as during sleep. To our knowledge, no previous study has evaluated the association of job strain with diurnal variation in PP. However, it is of interest that the diurnal variations in SBP and DBP reported in a previous longitudinal study, suggest that PP during sleep may have been more similar to PP during the day among participants who were classified by high job strain compared to those classified by low job strain (7). The disappearance of circadian PP implies that individuals with high job strain maintain higher ambulatory PP during the night compared to those with low job strain. Increased 24-hour PP is also associated with end-organ damage (28, 29).

While our primary analyses showed that job strain was an independent determinant of SBP dipping among men, exploratory analyses of job strain's component effects (job demands and control) showed that job control may have largely accounted for our findings for job strain. A negative association between job control and nighttime SBP was found in our study. Some previous studies also have found an association of job control with SBP by ABPM (10, 30, 31). Our study further demonstrated that men with low job control had significantly blunted SBP and PP dipping compared to men with high job control, which is consistent with the effect of job strain on nighttime BP. This finding reflects job control being an important component of the job demand–control model (32), supporting the possibility that improving employee's job control may mitigate health problems caused by job stress (33). It is worth noting that circadian PP was attenuated among men characterized by high job demands and low job control, in addition to high job strain. This observation suggests the possibility that circadian PP may be informative in other studies utilizing ABPM to explore the impact of job strain on BP.

The relationship between job strain and nighttime BP dipping was possibly due to the effect of job strain on sleep duration (34) and sleep quality (35). In a two-year Japanese prospective study, high job strain was independently associated with insomnia [odds ratio (OR) 1.55, 95% confidence interval (95% CI) 1.12–2.15] (36). At follow-up, among those who were not insomniacs at baseline, high job strain at baseline was associated with insomnia at follow-up (OR 1.72, 95% CI 1.06–2.79) (37). This biobehavioral mechanism is consistent with the evidence of a relationship between poor sleep quality and BP non-dipping (38).

Our study found that job strain was associated with blunted SBP dipping among men, but not women. These gender differences are consistent with the results from previous studies (1, 16–18) that have shown job strain tends to be associated with elevated BP among men rather than women. Among women, however, other studies have shown that there is an association between domestic stress and BP (39, 40), and higher home stress is also related to elevated sleep BP (41). It is worth noting that exposure to both job stress and domestic stress has a greater effect on women's BP than the exposure to either one of them alone (42, 43). These findings suggest the possibility that work–family conflict or domestic stress may be related to women's diurnal variation in BP. Further studies are needed to confirm this association.

In our study, both male and female participants with high job strain showed lower supervisor and coworker support than those with low job strain. A study from Columbia University showed that low social support was associated with non-dipping (44). Increased perceived social support, in another study, was related to the magnitude of SBP and DBP dipping (45). These findings, therefore, raise the possibility that improving social support may be an effective intervention to promote normal diurnal variation in BP.

Our study showed that high job strain was related to elevated BP only during sleep, which is not consistent with previous studies that explored the effects of job strain on 24-hour ABP. There are several possible explanations for this finding, which may reflect limitations in our study design. Participants in our study were from a wide range of occupations and it has been shown previously that postural differences across occupations may have a significant influence on work BP (39, 46). Also, our study sample was relatively small and comprised of men and women selected for their high clinic blood pressure, and participants characterized by high job strain were relatively few, which may have limited our ability to detect an association between workday BP and job strain characteristics. Our findings may not generalize to populations characterized by optimal blood pressure. It is also possible that BP during sleep better reflects the effects of job strain on BP by minimizing the potentially confounding environmental influence. In addition to the limitations inherent in the cross-sectional design of our study, including the preclusion of cause–effect inferences, selection bias might have been introduced by the self-selection of participants. As shown in table 1, men with high job strain had higher depressive symptoms and trait anxiety scores compared to men with low job strain. These psychological characteristics may also contribute to blunted nighttime BP dipping (14), and/or be a further manifestation of job strain (47). Importantly, however, in our study, the association of job strain with blunted nighttime BP dipping remained significant even after controlling for these psychological factors.

In summary, our study demonstrated that men, but not women, with high job strain had a significantly blunted SBP dipping and blunted PP dipping compared to men with low job strain. For men, the association between job strain and diurnal variation in SBP and PP may be a mechanism contributing to the observed relationship between job strain and increased risk of cardiovascular disease. These findings require replication in other designs and settings to establish their validity. Our findings suggest the possibility that modifying the work environment may help protect against the development of cardiovascular disease and preventive efforts should be directed not only at the individual but also at the workplace.

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