ORIGINAL ARTICLE

Psychosocial work environment and ambulatory blood pressure: independent and combined effect of demand-control and effort-reward imbalance models

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ABSTRACT

Background Two main theoretical models have been used to assess the impact of psychosocial work factors on blood pressure (BP): the demand-control model (DC) and the effort-reward imbalance (ERI) model. Little is known about their independent and combined effect.
Objective To examine the independent and combined effect of the DC and ERI models on ambulatory BP (ABP).
Method Data were collected three times over 7 years from 3395 white-collar women and men using a repeated cross-sectional design. On each occasion, psychosocial work factors were measured using validated scales. ABP was measured every 15 min during a working day. Systolic and diastolic ABP means were examined in relation to contemporaneous and past exposure. Both models were mutually adjusted. A combined exposure variable was computed.
Results In men, high strain, and active, passive and ERI exposure were associated with ABP using contemporaneous exposure. However, the high strain/ABP association was not significant after adjustment for ERI. In women, no association was found with the DC model, while women exposed to ERI had higher ABP. Use of past exposure showed a stronger association between ABP and active exposure in men, while ERI associations were attenuated. Combined exposure to active jobs and to ERI was associated with ABP in both genders.
Conclusions In men, associations with the DC model were mixed. Associations between high job strain and ABP were not independent of ERI exposure while both DC intermediate groups were independently associated with ABP. In women, no association was found with the DC model. ERI exposure was independently associated with ABP using contemporaneous exposure, but not using past exposure. Combined active and ERI exposure was also associated with ABP.

What this paper adds

- A growing body of research has investigated the adverse effects of psychosocial work factors from the demand-control (DC) model and from the effort-reward imbalance model (ERI) on blood pressure (BP), but little is known about their independent and combined effect.
- In the present study, conducted in more than 3000 white-collar workers, high job strain, active and passive exposure were associated with ABP in men. Associations between high job strain and ABP were not independent of ERI exposure. In women, no association was found with the DC model.
- Both DC intermediate groups (active and passive) were independently associated with BP.
- ERI exposure was independently associated with BP using contemporaneous exposure but not using past exposure.
- Combined active and ERI exposure was also associated with BP.
- These results suggest that preventive interventions could target adverse psychosocial work factors from both models in order to reduce their impact on cardiovascular health.

INTRODUCTION

Two main theoretical models are used to assess the impact of psychosocial work factors on blood pressure (BP). The demand-control model (DC) suggests that workers simultaneously experiencing high psychological demands (PD) and low decision latitude (DL) (ie, job strain) are more likely to develop stress-related health problems.[1] PD reflect quantity of work, time constraints, and level of intellectual effort required. DL is a combination of skill discretion and decision authority. Siegrist's effort-reward imbalance (ERI) model proposes that efforts should be rewarded in various ways: income, respect and esteem, and occupational status control.[2] Workers are in a state of detrimental imbalance when high efforts are accompanied by low reward, and thus more susceptible to health problems. These models are related but cover somewhat different aspects of the psychosocial environment at work. The demands and efforts variables are similar. However, the DC focuses on task-level characteristics, while the ERI focuses on broader socioeconomic conditions, such as salaries, promotion prospects and job stability. Current work and labour market trends such as downsizing, poor job security and a decline in permanent jobs, challenge the manner work stress is conceptualised and measured.[3] As the DC and ERI models capture different dimensions of stress at work, combining them might provide additional insights into the effect of the psychosocial work environment on health.

Previous studies have examined the simultaneous effects of both models.[4–15] In those studies, either model (or some of their specific dimensions) was

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independently associated with various health outcomes (physical and psychological well-being, depression, self-rated health), suggesting that they cover distinctive psychosocial factors. The contribution of both models as determinants of BP has been evaluated in two studies.[7 8] The first study, conducted among men only, evaluated the combined effect of DC and ERI exposure. In this study, workers exposed to adverse psychosocial work factors from both models had twice the hypertension prevalence of unexposed workers.[7] In the second study, which evaluated the independent effect of both models, DC and ERI exposure was not associated with hypertension. However, low job control and low job demands were, after controlling for the effect of ERI exposure. This study was conducted among part-time female employees of a retail company where exposure to an adverse psychosocial work environment would have been limited because of the restricted working hours.[8] Both studies also share other limitations, that is, the use of a gender restricted sample and the use of casual BP (CBP) measurements. CBP measurements do not adequately reflect BP variations over the entire day. Moreover, it is recognised that ambulatory and home BP monitoring better predicts target organ damage and cardiovascular event risk.[16 17]

The aim of the present study is to examine the independent and combined effect of both psychosocial work environment models on ambulatory BP (ABP).

METHODS

Population and study design

The study relies on a repeated cross-sectional design involving three cross-sectional waves of data collection over 7 years (years 1, 5 and 7). The study population was composed of white-collar workers from three public insurance institutions. Their main activities were planning and providing insurance services to the general population. The employees occupied the full range of white-collar positions, and included senior and middle managers, professionals, technicians and office workers. Employees completed a self-administered questionnaire on work characteristics and BP risk factors in a dedicated room at the workplace. All employees of the organisations were invited to participate in each collection event. The participation rate was 79.5% at baseline and 85% at each follow-up measurement. Across all three measurement times, we have excluded 862 observations due to insufficient or unavailable BP measurements and 80 observations reported by pregnant women. We have also excluded 33 observations for insufficient working time (less than 21 h), to prevent misclassification caused by limited exposure to adverse psychosocial work factors. The final study sample consisted of 3676 workers and 7190 observations. These workers participated in one (n=1326), two (n=1186) or all three (n=1164) measurements. A total of 2157 workers participated in year 1, 2625 in year 5 and 2408 in year 7. At each time point, missing data on exposure variables or covariates ranged from 0% to 3.6%.

The study sample for past exposure analyses is different, as eligible workers must have participated in at least two consecutive waves of data collection. As such, fewer workers were included in the analyses (2355 workers and 3553 observations). Estimates from the cross-lagged analysis were adjusted for the difference in the time interval occurring between the baseline and first follow-up and between the first and the second follow-up, with a time covariate added which captures the average effect of time on ABP.

Psychosocial work factors

We measured both components of the DC model using 18 items from the Job Content Questionnaire (JCQ).[18] PD refer to an excessive work load, very hard or very fast work, task interruption, intense concentration, and conflicting demands. DL reflects opportunities for learning, autonomy and participation in the decision-making process. The psychometric properties of the original entire JCQ scale of 18 items[19 20] and its French[20–23] version have been previously demonstrated. We have used the proposed quadrant method to classify subjects into four groups. Workers with PD scores of 24 or higher (the median for the general Québec working population) were classified as having high PD. Workers with DL scores of 72 or lower (the median for the general Québec population) were classified as having low DL.[24] The passive group comprised of workers with low PD and low DL, the active group comprised of workers with high PD and high DL, and the job strain (high strain) group comprised of workers with high PD and low DL. Other workers were classified as unexposed. In a complementary analysis, job strain was also operationalised as a continuous variable, using the ratio between PD and DL.[25] As expected, effect measures were lower, as this formulation does not fully capture the effect observed for active and passive workers. Results from this analysis are available on request.

Reward was assessed using the French version of the 11 original items recommended by Siegrist.[2] The items were divided into three scales: esteem (five items), promotions and salary (four items) and job security (two items). The factorial validity and internal consistency of both versions (English and French) have been demonstrated.[26] Effort was measured with two original items from the Siegrist questionnaire (‘Over the past few years, my job has become more and more demanding’ and ‘I am regularly forced to work overtime’) and with two proxies (‘My tasks are often interrupted before they can be completed, requiring attention at a later time’ and ‘I have enough time to do my work’) (Cronbach’s α=0.69). A ratio of efforts to rewards greater than 1 indicated an ERI. The ERI ratio was also divided into tertiles.

Conceptual overlap between models may arise from similarities between DC and ERI dimensions.[7] As expected, the correlation between demands and efforts (in their continuous formulation) was high (r=0.80). The correlation between DL and rewards was lower (r=0.42). Finally, the correlation between DC and ERI was also substantially lower, both in their continuous and categorical formulations (r=0.51 and r=0.54, respectively). Analyses using combined high strain (yes/no) and ERI exposure were performed and no significant association with ABP was observed (not shown). However, this combined exposure variable introduced exposure misclassification, regrouping unexposed, passive and active workers into the same category. In an exploratory (post hoc) analysis, an additional combined exposure variable was computed according to the following categories: (1) neither ERI nor exposure to an active job present; (2) ERI present but active exposure absent; (3) active exposure present but ERI absent; and (4) both ERI and active job exposure present. For combined exposure analyses, a ratio of efforts to rewards greater than 1 indicated ERI. Analyses using the ERI top tertile yielded similar results.

Ambulatory blood pressure

ABP was assessed using Spacelabs 90207 monitors (Produits Médicaux Spacelabs, St-Laurent, Québec, Canada) validated by the independent investigators’ protocol recommended by the Association for the Advancement of Medical Instrumentation and the British Hypertension Society.[27 28] The first three measurements, taken in the presence of staff, were excluded. ABP was defined as the mean of all subsequent readings taken during the working day. The device was installed on the non-dominant arm if the BP difference measured on both arms was less than 10 mm Hg. Otherwise, it was installed on the arm with the higher BP level. ABP was measured every 15 min during regular working hours (from 8:00 to 16:00). Therefore, the dependant variable was mean work time ABP.

Covariates

Several factors were considered as potential confounders including cigarette smoking status, body mass index (BMI), alcohol intake and physical activity. Smoking status was defined as the daily consumption of at least one cigarette. Body weight and height were measured to calculate BMI (kg/m^2). Alcohol intake was measured using the following three categories related to intake frequency during the past 12 months: less than one drink per week, one to five drinks per week, and six and more drinks per week. Participants were further classified by their weekly leisure physical activity frequency, namely, three times a week, two times a week, and once or less a week. Other factors also considered as potential confounders were age and a family history of cardiovascular disease (CVD). The definition of the latter group was based on the declaration by the participant of a cardiovascular event, such as angina, myocardial infarction, coronary revascularisation or stroke, experienced by their father, mother, brother or sister before the age of 60 years. The risk factors listed above were evaluated using validated protocols.[24 29]

Analyses

The χ^2 test was used to compare participant characteristics. Generalised estimating equations (GEE) were used to examine the association between exposure to psychosocial work factors and BP.[30] We included all employed individuals at each measurement time in the analyses. The repeated cross-sectional design used in the present study is particularly well suited for analyses of dynamic populations, such as work organisations, as it accommodates new participants' in-migration. GEE provide estimates of marginal means and take into account within-subject correlation.[31] ABP means were estimated according to contemporaneous exposure. Each observation contains a participant's current exposure and current worktime mean ABP. We also used a cross-lagged GEE model to examine whether psychosocial work factors were associated with BP at the next measurement time (past exposure analysis). The assumption here was that psychosocial work factors may be more strongly related to BP when time is allowed to elapse between exposure and outcome. Means differences between exposed and unexposed workers and their respective p values were computed. The level of statistical significance was set at 0.05. We presented crude and adjusted models. It should be noted that lifestyle risk factors might act as mediating variables, that is, they may intervene in the causal pathway linking work stress to BP.[32 33] We have therefore proposed two additional models: (1) adjusted for sociodemographic and BP-related variables (age, education, family history of CVD and medication for hypertension) and (2) additionally adjusted for lifestyle variables (smoking, BMI, recreational physical activity and alcohol intake). If some of these lifestyle variables were true mediators, adjusting for them would result in an underestimation of the true overall effect of work stress on BP. We have also examined an alternative method to deal with medication, which consists of adding a constant to the systolic (+10 mm Hg) and diastolic (+5 mm Hg) ABP means of treated participants.[34 35] This method yielded similar results (not shown). The data from each measurement time were pooled. All analyses were conducted separately for each gender. All covariates were assessed at each measurement time. We have therefore considered them as time-varying covariates, in order to take into account within-subject variation. SAS V.9.1 software was used for all analyses. This study was approved by the ethics review board of the CHU de Québec.

RESULTS

Table 1 summarises the participants' characteristics. The participants' mean age was 45.4 (SD 8.3) years for men and 43.4 (SD 7.4) years for women (p<0.001). Mean ABP was 130.09/82.78 mm Hg (SD 10.7/7.9) in men and 122.01/78.06 mm Hg (SD 10.3/7.4) in women (p<0.001). Men and women were comparable regarding ERI exposure at baseline: 36.1% of men and 36.1% of women were exposed to the highest ERI tertile. However, women were more likely to be exposed to job strain

Table 1 Characteristics of the study population at baseline

	Men N (%)	Women N (%)	p Value
Mean age	45.4 (8.3)	43.4 (7.4)	<0.001
Body mass index (kg/m^2)			<0.001
<25	291 (33.0)	685 (54.2)	
25–26.9	196 (22.2)	182 (14.4)	
≥27	395 (44.8)	396 (31.4)	
Physical activity			
≥1/week	774 (87.6)	1047 (82.6)	0.0008
<1/week	107 (12.2)	221 (17.4)	
Education			
Less than college	146 (16.5)	427 (33.5)	<0.001
College	250 (28.3)	394 (30.9)	
University	487 (55.2)	453 (35.6)	
Family history of CVD			
No	600 (69.9)	803 (65.3)	0.03
Yes	259 (30.1)	426 (34.7)	
Alcohol intake			
<1 drink/week	250 (28.4)	488 (38.3)	<0.001
1–5 drinks/week	337 (38.2)	554 (43.5)	
≥6 drinks/week	294 (33.4)	231 (18.2)	
Smoking status			
No	774 (87.9)	1089 (85.5)	0.113
Yes	107 (12.1)	185 (14.5)	
Mean systolic ABP	130.09 (10.7)	122.01 (10.3)	<0.001
Mean diastolic ABP	82.78 (7.9)	78.06 (7.4)	<0.001
ERI ratio			
1st tertile	261 (29.7)	406 (32.1)	0.3706
2nd tertile	301 (34.2)	401 (31.8)	
3rd tertile	317 (36.1)	456 (36.1)	
Job strain			
Unexposed	192 (21.9)	163 (12.9)	<0.001
Passive	273 (31.2)	534 (42.3)	
Active	256 (29.2)	284 (22.5)	
Exposed	155 (17.7)	282 (22.3)	
Mean psychological demands	23.4 (3.7)	23.2 (4.1)	0.2575
Mean decision latitude	73.03 (11.1)	68.72 (11.7)	<0.001
Mean efforts	10.1 (2.1)	9.9 (2.2)	0.0634
Mean rewards	31.8 (4.4)	31.6 (4.5)	0.3222

ABP, ambulatory blood pressure; CVD, cardiovascular disease; ERI, effort-reward imbalance.

Table 2 Ambulatory blood pressure means according to decision latitude, psychological demands, efforts and rewards

	N	Systolic ABP (mm Hg) Crude mean	Adjusted mean†	Adjusted mean‡	Diastolic ABP (mm Hg) Crude mean	Adjusted mean†	Adjusted mean‡
Men							
Low decision latitude							
T1	1220	129.3	129.3	129.2	82.3	82.2	82.2
T2	950	+0.22	+0.23	+0.30	−0.07	−0.04	+0.02
T3	683	−0.80	−0.78	−0.54	−0.44	−0.24	−0.15
Psychological demands							
T1	633	127.7	127.6	127.8	81.1	81.2	81.3
T2	1230	+1.29*	+1.28*	+1.05*	+0.82*	+0.68	+0.58
T3	997	+2.84*	+2.94*	+2.48*	+1.94*	+1.90*	+1.69*
Efforts							
T1	839	128.1	128.2	128.5	81.2	81.5	81.6
T2	1024	+0.84	+0.60	+0.28	+0.89*	+0.52	+0.34
T3	996	+2.49*	+2.16*	+1.76*	+1.95*	+1.47*	+1.24*
Low rewards							
T1	1050	129.1	129.2	129.3	81.8	82.1	82.2
T2	855	+0.30	−0.07	−0.30	+0.51	−0.03	−0.17
T3	962	+0.28	−0.07	−0.29	+0.57	+0.13	−0.007
Women							
Low decision latitude							
T1	1206	122.1	122.0	121.9	77.8	77.7	77.6
T2	1379	−0.26	−0.26	−0.11	+0.03	+0.11	+0.25
T3	1723	−1.15*	−1.09*	−1.11*	−0.77*	−0.51	−0.40
Psychological demands							
T1	1099	120.5	120.5	120.5	76.6	76.6	76.7
T2	1742	+1.05*	+1.16*	+1.04*	+0.93*	+0.86*	+0.77*
T3	1467	+1.78*	+1.76*	+1.59*	+1.71*	+1.55*	+1.39*
Efforts							
T1	1241	120.5	120.7	120.6	76.6	76.7	76.6
T2	1464	+1.03*	+0.70	+0.94*	+0.93*	+0.82*	+0.98*
T3	1574	+1.92*	+1.48*	+1.52*	+1.67*	+1.46*	+1.42*
Low rewards							
T1	1436	121.0	121.2	121.3	77.1	77.2	77.2
T2	1296	+0.78	+0.43	+0.29	+0.52	+0.40	+0.33
T3	1577	+0.92*	+0.46	+0.17	+0.77*	+0.58	+0.45

*Stand for p value <0.05.
†Adjusted for age, education and family history of CVD and medication for hypertension.
‡Additionally adjusted for smoking, BMI, sedentary behaviour and alcohol intake.
ABP, ambulatory blood pressure; BMI, body mass index; CVD, cardiovascular disease; T1, first tertile; T2, second tertile; T3, third tertile.

than men (22.3% vs 17.7%). Women were generally less educated than men and were also less likely to consume alcohol in excess. However, women were more likely to maintain a sedentary lifestyle or report a family history of CVD.

Table 2 presents the systolic and diastolic ABP means according to each psychosocial factor considered separately. ABP means are presented by tertiles of DL, PD, efforts and reward. Women with low DL had lower systolic ABP (−1.11 mm Hg), while no association was found for men. Men and women in the highest PD tertile had higher mean systolic and diastolic ABP (+2.48/+1.69 mm Hg and +1.59/+1.39 mm Hg, respectively). High efforts was also associated with higher ABP for men (+1.76/+1.24 mm Hg) and women (+1.52/+1.42 mm Hg). No association was found with low reward for either men or women.

ABP means according to contemporaneous exposure (standard GEE models)

Table 3 presents systolic and diastolic ABP measurements according to contemporaneous DC and ERI exposure. In men, high strain exposure was associated with systolic (+1.55 mm Hg) and diastolic (+1.44 mm Hg) ABP before adjustment for ERI exposure. These associations were no longer statistically significant in the analysis including both models (+0.84/+0.70 mm Hg, p>0.05). Active (+1.92/+1.31 mm Hg) and passive (+1.23/+1.10 mm Hg) workers had higher systolic and diastolic ABP compared to unexposed workers after adjustment for ERI exposure. Men in the highest tertile of ERI exposure had higher systolic (+1.85 mm Hg) and diastolic (+1.36 mm Hg) ABP means compared to workers in the lowest tertile. In women, no significant association with high strain was observed before or after adjustment for ERI exposure. However, passive women had lower systolic ABP (−1.02 mm Hg). Women in the highest ERI tertile had higher systolic (+1.57 mm Hg) and diastolic (+1.29 mm Hg) ABP means compared to women in the lowest tertile after adjustment for DC exposure.

ABP means according to past exposure (cross-lagged GEE models)

Table 4 presents systolic and diastolic ABP means according to past DC and ERI exposure. In men, the association with high

Table 3 Ambulatory blood pressure means according to contemporaneous job strain and ERI exposure (GEE, standard model)

		Systolic ABP (mm Hg)				Diastolic ABP (mm Hg)			
	N	Crude mean	Adjusted mean†	Adjusted mean‡	Adjusted mean§	Crude mean	Adjusted mean†	Adjusted mean‡	Adjusted mean§
Men									
Job strain									
Unexposed	660	127.6	127.6	127.8	128.1	80.9	80.9	81.0	81.3
Passive	905	+1.54*	+1.40*	+1.33*	+1.23*	+1.20*	+1.25*	+1.20*	+1.10*
Active	801	+3.10*	+2.98*	+2.50*	+1.92*	+2.22*	+2.14	+1.90	+1.31*
Exposed	482	+1.50*	+1.59*	+1.55*	+0.84	+1.34*	+1.45*	+1.44*	+0.70
ERI									
T1	940	128.0	128.0	128.2	128.4	81.0	81.2	81.3	81.4
T2	966	+1.38*	+1.19*	+0.98*	+0.79	+1.32*	+0.91*	+0.81*	+0.66
T3	952	+2.39*	+2.24*	+1.85*	+1.37*	+2.22*	+1.90*	+1.71*	+1.36*
Women									
Job strain									
Unexposed	605	121.6	121.7	121.6	122.0	77.5	77.5	77.4	77.7
Passive	1839	−0.87	−0.97	−0.91	−1.02*	−0.72	−0.60	−0.49	−0.57
Active	911	+0.86	+0.71	+0.68	+0.09	+0.65	+0.56	+0.48	−0.04
Exposed	945	+0.51	+0.41	+0.30	−0.44	+0.76	+0.81	+0.84	+0.18
ERI									
T1	1477	120.5	120.7	120.8	120.8	76.7	76.8	76.9	77.0
T2	1400	+0.74	+0.66	+0.54	+0.54	+0.50	+0.43	+0.34	+0.28
T3	1422	+2.34*	+1.89*	+1.59*	+1.57*	+1.86*	+1.61*	+1.46*	+1.29*

*Stand for p value <0.05.
†Adjusted for age, education and family history of CVD and medication for hypertension.
‡Additionally adjusted for smoking, BMI, sedentary behaviour and alcohol intake.
§Additionally adjusted for the other model.
ABP, ambulatory blood pressure; BMI, body mass index; CVD, cardiovascular disease; ERI, effort-reward imbalance; GEE, generalised estimating equations; T1, first tertile; T2, second tertile; T3, third tertile.

Table 4 Ambulatory blood pressure means according to past job strain and ERI exposure (GEE, cross-lagged)

		Systolic ABP (mm Hg)				Diastolic ABP (mm Hg)			
	N	Crude mean	Adjusted mean†	Adjusted mean‡	Adjusted mean§	Crude mean	Adjusted mean†	Adjusted mean‡	Adjusted mean§
Men									
Job strain									
Unexposed	336	126.8	126.9	127.1	127.4	80.7	80.8	80.8	81.1
Passive	436	+1.70*	+1.47	+1.28	+1.24	+1.40*	+1.49*	+1.44*	+1.38*
Active	415	+3.57*	+3.39*	+2.92*	+2.36*	+2.64*	+2.47*	+2.29*	+1.75*
Exposed	249	+1.74*	+1.74	+1.58	+0.90	+1.05	+0.97	+0.93	+0.22
ERI									
T1	463	127.2	127.2	127.5	127.8	81.0	81.1	81.3	81.4
T2	485	+1.53*	+1.60*	+1.30*	+1.08	+1.19*	+1.05*	+0.94	+0.80
T3	492	+2.43*	+2.40*	+1.91*	+1.26	+1.92*	+1.72*	+1.50*	+1.19*
Women									
Job strain									
Unexposed	300	121.4	121.4	121.2	121.4	77.3	77.3	77.1	77.3
Passive	885	−0.64	−0.60	−0.19	−0.25	−0.54	−0.43	−0.12	−0.17
Active	452	+0.97	+0.75	+1.07	+0.74	+1.01	+0.80	+0.90	+0.55
Exposed	458	+0.63	+0.56	+0.60	+0.22	+0.57	+0.47	+0.62	+0.19
ERI									
T1	714	120.5	120.8	121.0	121.1	76.7	76.8	76.9	77.0
T2	695	+0.73	+0.47	+0.37	+0.34	+0.63	+0.54	+0.44	+0.39
T3	686	+2.21*	+1.53*	+1.10	+0.90	+1.58*	+1.20*	+1.06*	+0.90

*Stand for p value <0.05.
†Adjusted for age, education and family history of CVD and medication for hypertension.
‡Additionally adjusted for smoking, BMI, sedentary behaviour and alcohol intake.
§Additionally adjusted for the other model.
ABP, ambulatory blood pressure; BMI, body mass index; CVD, cardiovascular disease; ERI, effort-reward imbalance; GEE, generalised estimating equations; T1, first tertile; T2, second tertile; T3, third tertile.

Table 5 Ambulatory blood pressure means according to combined active and ERI exposure (GEE, standard model)

	N	Systolic ABP (mm Hg)			Diastolic ABP (mm Hg)		
		Crude mean	Adjusted mean†	Adjusted mean‡	Crude mean	Adjusted mean†	Adjusted mean‡
Men							
Unexposed	1656	128.3	128.3	128.5	81.5	81.5	81.6
ERI exposure only	389	+1.67*	+1.62*	+1.45*	+1.51*	+1.38*	+1.28*
Active exposure only	477	+2.11*	+2.00*	+1.52*	+1.37*	+1.23*	+1.01*
Combined exposure	323	+2.79*	+2.66*	+2.15*	+2.10*	+1.91*	+1.66*
Women							
Unexposed	2699	120.9	120.9	121.0	77.0	77.1	77.1
ERI exposure only	681	+1.95*	+1.71*	+1.35*	+1.63*	+1.51*	+1.39*
Active exposure only	533	+0.69	+0.76	+0.78	+0.46	+0.35	+0.26
Combined exposure	377	+2.91*	+2.58*	+2.29*	+2.17*	+1.89*	+1.59*

*Stand for p value <0.05.
Exploratory (post hoc) analyses.
†Adjusted for age, education and family history of CVD.
‡Additionally adjusted for smoking, BMI, sedentary behaviour and alcohol intake.
Unexposed: neither ERI nor active present; Combined exposure: both ERI and active exposure present.
ABP, ambulatory blood pressure; BMI, body mass index; CVD, cardiovascular disease; ERI, effort-reward imbalance; GEE, generalised estimating equations.

strain observed previously for contemporaneous exposure (+1.55/+1.44 mm Hg) before ERI adjustment remained with past exposure (+1.58/+0.93 mm Hg), although it was no longer statistically significant. Active workers had higher systolic (+2.36 mm Hg) and diastolic (+1.75 mm Hg) ABP compared to unexposed workers after adjustment for ERI exposure and additional confounders. This association with past exposure was thus slightly higher than the contemporaneous association. Passive men also had higher diastolic ABP (+1.38 mm Hg). In women, no significant association with the DC model was observed. Men and women in the highest tertile of ERI exposure had higher systolic and diastolic ABP means compared to men in the lowest tertile. However, this association was weaker after adjustment for the DC model in both genders.

Combined active and ERI exposure

Table 5 presents ABP means according to combined active and ERI exposure. In men, workers for whom only active exposure is present showed higher BP means (+1.52 mm Hg for systolic and +1.01 mm Hg for diastolic ABP, respectively) compared to men unexposed to either stress model. Men who were exposed to ERI exposure only also showed higher ABP means compared to unexposed men (+1.45/+1.28 mm Hg). In women, workers exposed to ERI without active exposure showed higher systolic (+1.35 mm Hg) and diastolic (+1.39 mm Hg) means. Men and women exposed to both ERI and active exposure had higher ABP means (+2.15/+1.66 mm Hg and +2.29/+1.59 mm Hg, respectively). However, no effect modification on an additive scale was observed for this combined exposure variable.

DISCUSSION

In men, associations between high job strain and ABP were not independent of ERI exposure. Workers exposed to active and passive jobs had higher ABP means compared to unexposed workers. For active workers, this association was slightly stronger with past exposure. These effects for intermediate categories of the DC model in men were robust to adjustment for ERI. An independent effect of ERI on high BP in men and women was observed in the contemporaneous analyses, but this effect was mostly lost after adjustment for the DC model in past exposure analysis. Finally, combined exposure to an active job and to ERI was associated with higher ABP in both genders.

The associations observed for the DC model do not fully correspond with Karasek and Theorell's theoretical proposition.[1] The DC model hypothesised that active jobs are associated with a feeling of mastery which could reduce the psychophysiological impact of stressful situations at work, resulting in better cardiovascular health.[1] Higher ABP in the active workers might be partly attributable to new management practices which have led to work intensification.[36] These practices (downsizing, poor job security, a decline in permanent jobs and growth of temporary/fixed contract work) involve increased productivity expectations combined with higher work autonomy. However, in such conditions, high demands may be too high to be compensated by a gain in autonomy. More research is needed on how and to what extent such changes and related job conditions alter and/or complexify the pathogenic process linking demands, control and cardiovascular health. The association between passive jobs and ABP which was observed in the analyses, is somewhat harder to link to sound theoretical explanation. However, some empirical evidence is consistent with this result. Indeed, Cesana and colleagues[37] have previously demonstrated that passive men showed similar systolic BP values as highly strained men for both CBP and work ABP. Moreover, within their pooled analysis, these authors reported that passive men showed the highest prevalence of hypertension (diagnosed from CBP).[38] Our findings relied on a repeated cross-sectional design and were adjusted for other important and well documented psychosocial factors at work. They highlight the need to consider both intermediate job strain groups (active and passive), as both were associated with elevated ABP at work.

Associations between ERI and BP are consistent with the underlying conceptual model developed by Siegrist. In the present study, ERI and BP were generally related in a dose-response manner, therefore strengthening the causal plausibility of such associations. Only one previous study which evaluated the effect of ERI on BP has integrated adjustment for other well-documented psychosocial work factors.[8] No significant effect of ERI exposure on BP was reported. As stated earlier, this study has limitations related to the CBP measurements and a gender restricted sample. Also, hypertension, rather than BP means, was used as the outcome. Thus, these results cannot be easily compared with ours.

The present study has examined the effect of past exposure on ABP. In men, past exposure to active and passive jobs was associated with higher BP means. The associations between ERI and ABP were independent of the DC model in the contemporaneous analysis but not when past exposure was assessed. The present study suggests a minor attenuation of the ERI exposure effect when a lapse of time has occurred, consistent with the findings of Schnall *et al* for job strain.[39] However, the possibility of exposure misclassification cannot be ruled out given that duration of exposure was not assessed. This non-differential misclassification could have biased past exposure estimations toward the null. Duration of exposure is an important issue. Previous prospective studies have shown significant associations between repeated exposure to high strain[39–42] or to ERI[43] and ABP. These previous investigations have methodological limitations which were avoided in the present study. First, the participant must be present at each time point in order to assess within-subject changes in exposure, resulting in power loss. Secondly, repeated exposure relied on a binary definition of high strain at each time point, in order to have a reasonable number of categories, resulting in misclassification of the active and passive groups. The present study highlights the necessity of avoiding this exposure misclassification. A thorough examination of exposure duration was beyond the scope of the present study but will be examined in a future paper.

The present study showed significantly higher systolic and diastolic ABP means among men and women with combined active and ERI exposure. In the only previous study which evaluated combined exposure to DC and ERI, workers exposed to high strain and to ERI had a hypertension prevalence twice that of unexposed workers.[7] Methodological issues such as the method of BP measurement and outcome selection (hypertension vs ABP means) could help explain these divergent results.

Our study has some limitations. First, our modelling strategy did not allow us to investigate exposure duration, and therefore misclassification biases are also possible. Such a bias may have also been introduced by the 4-point Likert scale used to assess ERI items. However, at the follow-up measurements, both the 4- and original 5-point scales were available and showed satisfactory correlations (r=0.78 for effort and r=0.80 for reward). Also, an approximate scale of effort was used. Even though the Cronbach's α was satisfactory (0.69), this could also have introduced a non-differential misclassification bias. Information about prevalent CVD or other chronic medical conditions was not available and therefore could not have been taken into account in the analyses. Finally, the study cohort was composed of white-collar workers, so results may not generalise to other populations. However, white-collar employees were selected to minimise physical work constraints that can influence the association between psychosocial work factors and BP, either by confusion and/or interactions.

Our study has important strengths. (1) It recruited a large sample of white-collar workers. (2) There was a high participation rate at each time point. (3) The study was conducted among men and women, thus allowing the investigation of gender-specific relationships between psychosocial factors at work and BP. (4) It used ABP measurements which are known to avoid observer error, the 'white-coat effect' and masked hypertension. ABP measurements also offer better validity and precision by capturing the BP fluctuations related to daily life. (5) It employed validated scales to assess psychosocial work factors from both stress models. (6) Both contemporaneous and past exposure analyses were used.

Finally, associations between psychosocial work factors and ABP found in the present study, although modest, may have an important impact on population health. Indeed, at the population level, a 2 mm Hg reduction in mean systolic BP would result in 10% fewer deaths from stroke and about 7% fewer deaths from ischaemic heart and vascular diseases in middle age.[44 45] Small increments in BP values between exposed and unexposed workers could be an important pathway by which work-related psychosocial exposure contributes to the damaging processes leading to CVD.

CONCLUSION

In men, associations with the DC model were mixed. Associations between high job strain and ABP were not independent of ERI exposure while both DC intermediate groups were independently associated with ABP. In women, no association was found with the DC model. ERI exposure was independently associated with ABP using contemporaneous exposure, but not using past exposure. Combined active and ERI exposure was also associated with ABP. Further prospective studies are needed in order to clarify the length of time before psychosocial exposure at work has an effect on BP.

Contributors XT supervised and synthesised the data analyses and led the writing. CB originated and supervised all aspects of the study. AM supervised the aspects of the study related to blood pressure measurement and interpretation. MV supervised the public health and work-related issues of the study. BM supervised data analyses. All authors participated in reviewing and drafting the article.

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Psychosocial work environment and ambulatory blood pressure: independent and combined effect of demand-control and effort-reward imbalance models

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