Work stressors and cardiovascular disease

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Over the past 20 years, an extensive body of research evidence has documented that psychosocial work stressors are risk factors for hypertension and cardiovascular disease. These stressors, which appear to be increasing in prevalence, include job strain (the combination of psychological job demands and low job control), imbalance between job efforts and rewards, threat-avoidant vigilant work, and long work hours. This article reviews the evidence linking these stressors with hypertension and CVD, and the physiological and social psychological mechanisms underlying the associations. Also described are methods for measuring work stressors and new, more accurate techniques for measuring blood pressure. Finally, strategies for reducing work stressors and preventing hypertension and CVD are reviewed. These include clinical assessment, worksite health promotion, work organization interventions, legal approaches and work site surveillance.

1. Introduction

Over the past 20 years, an extensive body of research evidence has documented that psychosocial work stressors are risk factors for hypertension and cardiovascular disease (CVD). The research findings, which have been recently reviewed in a book [1], are summarized in this article. In addition, the article describes methods for measuring work stressors and blood pressure, as well as strategies for reducing work stressors and preventing hypertension and CVD through clinical practice, worksite health promotion and work organization interventions.

1.1. Cardiovascular disease

CVD is the major cause of morbidity and mortality in the industrialized world. In the US, it is the cause of 41% of all deaths [2]. It is projected that CVD "worldwide will climb from the second most common cause of death . . . in 1990, to first place, with more than 36% of all deaths in 2020" [3, p. 1364].

One of the most dramatic successes of modern medicine and the public health movement is the decline of CVD mortality in industrialized countries over the past 4 decades [4]. The decline in CVD mortality in developed countries appears to be due primarily to reductions in some risk factors among CVD patients, and, to a lesser extent, medical interventions [5–8]. However, declines in CVD incidence (the rate of new cases of CVD) have been much smaller. Studies in Denmark [9] Finland [10] Sweden [11–13] and the US [7,14,15] have shown little or no decline in CVD incidence over the past 20 years.

For persons at risk of developing CVD, it appears that declines in some risk factors (e.g., smoking, cholesterol, mean blood pressure) may be counteracted by increases in others (e.g., overweight [16], diabetes [17]), along with little change in others (e.g., sedentary behavior [18,19], hypertension [20,21]), with a corresponding minor effect on incidence. The prevalence of hypertension in the US remains high, i.e., three-fourths of African-Americans and half of whites aged 60–74 [22].

Social factors, such as socioeconomic status (SES), gender, race, and working conditions, are likely to be important in understanding these trends. For example, there is a considerable and consistent body of evidence that lower SES is associated with greater CVD [23, 24]. The gap between higher and lower SES in CVD

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mortality [25,26] and incidence [11,27] is actually increasing. In fact, in one study, CVD incidence rates are increasing in blue-collar workers [27]. Higher CVD risk is not limited to those in poverty or without health insurance. In a major study of British civil servants, each step up the SES ladder was associated with a lower risk of death from all causes or from CVD [28,29]. More than half of the increased risk of heart disease death due to lower job status could not be explained by the standard risk factors such as smoking, cholesterol and hypertension.

What might other explanations be? The material conditions of life such as "housing, nutrition, child care facilities, physical working conditions and possibilities for recreation are all likely to follow people of higher" social class [25, p. 665]. More advantaged communities have greater resources for the promotion of "hygienic" life-styles and the "reduction of alienating living and working conditions which are conducive to initiating and maintaining unhealthful behaviors" [30, p. 925]. Sedentary behavior and smoking "often arise in the context of individuals trapped in low-control work environments" [31, p. 162]. The distribution of job control appeared to be "the biggest factor contributing to the socioeconomic gradient in CHD risk across civil service employment grade" [31,32]. The contemporary work environment is the locus in which adults now spend the majority of their waking hours, performing activities which are increasingly characterized, both by scientists as well as by the affected working people themselves, as demanding, constraining, and in other ways highly stressful. Therefore, we focus in this article on the extensive and growing body of research evidence which documents the important role played by psychosocial work stressors in increasing risk of hypertension and CVD.

1.2. Work stressors

A number of different models of work stressors have been investigated. The most highly studied construct is "job strain", i.e., work which combines high psychological work demands with low job decision latitude, or job control [33] (Fig. 1). More recently, the "effort-reward" model of work stressors has been described. This model defines threatening job conditions as a "mismatch between high workload (high demand) and low control over long-term rewards" [34, p. 1128]. Effort is defined as either the demands of the job ("extrinsic effort") or the personality characteristic of "overcommitment" to the job ("intrinsic effort"). Low reward includes concepts such as low "esteem reward" (e.g., respect, support, fair treatment), low income, and low "status control" (e.g., poor promotion prospects, job insecurity, downward mobility, status inconsistency). In addition, a number of studies have examined "threat-avoidant" vigilant work, i.e., work that involves continuously maintaining a high level of vigilance in order to avoid disaster, such as loss of human life [35,36]. This is a feature of a number of occupations at high risk for CVD, e.g., bus, taxi and truck drivers, air traffic controllers, and sea pilots. Long work hours, as another type of work stressor, has also been investigated. Prolonged exposure to stressful working conditions appears to be particularly deleterious [37].

1.3. Current economic and workplace trends

Current economic and workplace trends, which may be having dramatic effects on the health of lower SES groups [38–40], include various effects of the global economy, such as stagnant or falling income, downsizing, contingent and temporary work and new management systems such as "lean production" which intensify work [41]. The US Departments of Labor and Commerce report that the "stagnation of real earnings and increased inequality of earning is bifurcating the US labor market, with an upper tier of high wage skilled workers and an increasing 'underclass' of low paid labor". The US "is the most unequal among developed countries" [42, p. 19] and US income inequality is at the highest level of the past 60 years [43,44].

Substantial changes in job characteristics have also occurred over the past generation. In Europe, "time constraints" (i.e., workload demands) increased between 1977–96 [45], and in the US, increases between 1977–97 were reported for "never enough time to get everything done on my job" (from 40% to 60%) [46]. US workers' average weekly work hours increased by 3.5 to 47.1 hours from 1977–97 [46] and are now the longest in the developed world [47]. The average US married-couple family worked 247 more hours in 1996 than 1989 [48]. Somewhat increased job control has also been reported. In Europe, the proportion of workers reporting some measure of autonomy over their pace of work increased from 64% in 1991 to 72% in 1996 [49]. In the US, "freedom to decide what I do on my job" increased from 56% in 1977 to 74% in 1997 [46]. However, the proportion of "high strain" (high demand-low control) jobs in Europe has increased from 25% to 30% between 1991–96 [45]. Therefore, workplace risk factors may be playing a substantial role in maintaining or increasing incidence rates for CVD.

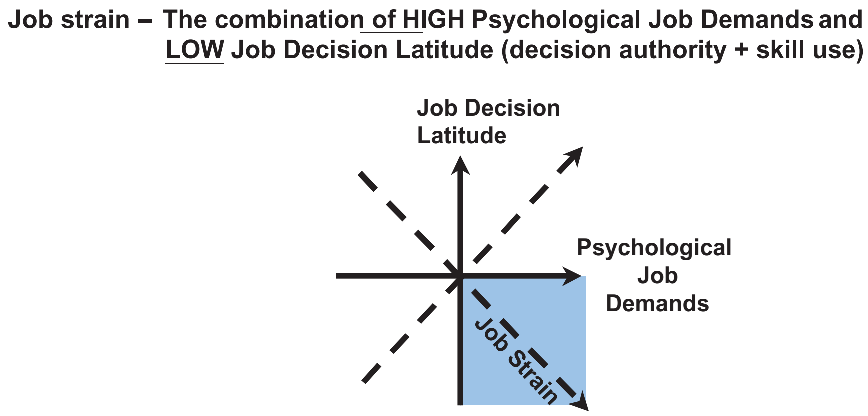

Fig. 1. Job strain – The combination of HIGH Psychological Job Demands and LOW Job Decision Latitude (decision authority + skill use).

2. Research on work stressors and CVD risk

Several reviews have been published on the association between these psychosocial work stressors and CVD [36,50,51]. There have been 24 studies of job strain and CVD (primarily coronary heart disease, CHD) among men [36], and 6 studies among women [52], most with significant positive associations. These have been conducted primarily in Sweden and the US, but also in England, Finland, Denmark and the Czech Republic. The component of low decision latitude (low control) has a more consistent association with CVD risk than does psychological job demands.

Of five studies of effort-reward imbalance among men in Germany [34,53], England [54], Finland [55, 56] and Sweden [57], all have found significant positive associations between exposure and CVD. No studies of effort-reward and CVD in women have been published to date. One British study [54] found that the effects of job strain and effort-reward imbalance were statistically independent of each other in the prediction of CHD and a Swedish study [57] found that the combined effects of exposure to job strain and to effort-reward imbalance upon CVD were much stronger then the separate effects of each model.

Only a few epidemiologic studies have specifically examined aspects of threat-avoidant vigilant activity and CVD outcomes. Significant associations with death due to heart attacks were found for "economic and financial implications of decisions taken at work, as well as the relevance of possible damage and hazards both economic and for human life as a consequence of possible mistakes made at work" among Italian male railroad workers [58]. In the US, cardiovascular disability was associated with the job dimensions "alert to changing conditions" and "hazardous job situation" [59]. Swedish men whose jobs entailed risk of explosion had an increased risk of hospitalization for myocardial infarction (MI) [60]. Finnish municipal employees whose jobs entailed "alertness of the senses" and dangerous work were at increased risk of CHD [61]. The strongest evidence for this risk factor comes from studies of single occupations, where professional drivers, particularly urban transport operators (a classic example of threat avoidant vigilant work), emerge as the occupation with the most consistent evidence of elevated risk of CHD and hypertension [62].

The association between work stressors and CVD is observed among both men and women, although the pattern of impacts are somewhat different probably because of differences in work conditions and extra-occupational stressors by gender. Among men, the impact of job strain on CVD is more consistent and stronger for blue-collar workers [63–67], with risk ratios as high as 10.0 [67], than among men in jobs with higher socioeconomic status.

Among women, in the Framingham Heart Study, 8-year heart disease incidence for clerical workers was double the rate for white-collar workers [68] and 14-year incidence among blue-collar women was more than triple the rate for white-collar women [69]. 20-year risk of MI or coronary death showed little difference between the clerical, blue-collar and white-collar groups. However, low education, having a husband with a clerical or blue-collar occupation (vs. white-collar), worry about money, and infrequent vacations were associated with increased risk [70]. The association between job strain and CHD among Framingham clerical women was 5.2, substantially higher than the OR = 2.9 for all women [71]. Framingham clerical workers who developed CHD did not differ on standard risk factors but were more likely to suppress hostility, have a non-supportive boss and to experience fewer job changes [68]. In addition to work stressors, "in most societies the traditional gender role patterns often persist with regard to home and family responsibilities" [31, p. 162]. The combination of work and home stressors may help to explain increased CHD risk in lower SES women. For example, in Framingham, 8-year CHD incidence among clerical workers with children (15.4%) was nearly triple that of non-clerical workers whether they had children or not. The highest risk group for 8-year incidence (21.3%) was clerical mothers married to blue-collar workers [68].

2.1. *Work stressors and hypertension*

A number of studies have explored whether the increased risk of CVD due to job strain is mediated by the effect of job strain on an important CVD risk factor, high blood pressure. Few studies of job strain and blood pressure (BP) measured in a clinic have shown significant associations [50]. However, strong evidence of an association is found in studies where BP is measured by an ambulatory blood pressure monitor [36]. The explanation for this difference in findings is that there are substantial problems with "casual" blood pressure (BP) measurements, such as those taken in a clinic or doctor's office. For example, relaxation can occur when people are away from work resulting in lower blood pressure. In addition, there are a number of atypical psychosocial stimuli present in a clinic that can affect BP, such as anxiety due to seeing a doctor. Because such stimuli are unique and unrelated to the majority of causal factors which influence BP they may produce temporary states unrelated to a person's typical BP. A more reliable and valid method of measuring BP is ambulatory (portable) monitoring, in which a person wears an automatic monitor on their arm throughout the work day [72]. Compared to casual BP measurements, ambulatory monitoring provides a more reliable measure of BP, since there is no observer bias and the number of readings is increased. It is also a more valid measure of average BP than casual (clinic) BP measurements, since BP is measured during a person's normal daily activities and exposure to the daily stressors that influence persistent increases in blood pressure. Ambulatory blood pressure is a better predictor of target organ damage, such as increases in the size of the heart's left ventricle, and CVD, than are casual clinic BP readings [72,73].

Of 10 cross-sectional studies of job strain (or its components) and ambulatory BP among men, many indicate significant positive associations with work BP [74–80] as well as dose-response relationships. In the five studies where measurements were also made outside of work, job strain was associated with leisure time systolic BP. Both cohort studies of ambulatory BP found significant associations with job strain among men [77, 81]. Of the six cross-sectional studies of job strain and ambulatory BP among women, four indicate a significant positive association with work systolic BP [78, 82–84]. Work systolic BP in men facing job strain is typically 4–8 mm Hg higher than those without job strain. In studies of women, estimates of the magnitude of effect have been even higher.

Three studies of high effort/low reward at work have examined hypertension as an outcome. These have shown significant positive associations with hypertension in men [85], and in men and women [86] and with a comanifestation of hypertension and high LDL-cholesterol in men [87]. Finally, two recent studies from Japan have shown an association between long work hours, independent of other workplace stressors, and elevated BP [88,89].

2.2. *Occult workplace hypertension*

Recent data suggest that there is a substantial prevalence of hidden workplace hypertension, that is, employees with normal "casual" blood pressure but elevated true blood pressure measured through ambulatory monitoring [90]. The data suggest that when individuals first are exposed to workplace stressors, BP is elevated at work and casual BP remains normal. Thus, the early development of work-related hypertension cannot be easily identified with casual clinic BP. Consequently, the etiologic role of work stressors in the development of essential hypertension can be obscured by relying solely upon casual clinic blood pressure measurements [90]. This finding also has implications for the design of worksite prevention and surveillance programs because they cannot rely on casual BP measurements to identify workers at risk.

2.3. *Results from the Work Site Blood Pressure* (*BP*) *Study*

The Work Site BP Study, a longitudinal study of psychosocial factors and ambulatory BP [77,91–93] was begun at Cornell University Medical College in 1985 in New York City. In this study, job strain, or "high strain" jobs, were defined as self-reported psychological job demands above the sample median combined with job decision latitude below the median.

At the first round of data collection (Time 1), men employed in "high strain" jobs were at increased risk of hypertension (OR $= 2.9$) [93], had increased left ventricular mass index (7.3 g/m^2) [91], and had higher levels of work (6.7 mm Hg systolic, 2.7 mm Hg diastolic), as well as home and sleep ambulatory BP (AmBP), controlling for potential risk factors such as age, body mass index (BMI), race/ethnic group, current alcohol use, current smoking status, 24-hour urine sodium excretion, education level, Type A behavior, physical exertion level of the job and worksite [92,93].

Examining data from Time 1 and a second round of data collection 3 years later (Time 2), it was possible to construct a measure of repeated or cumulative exposure to job strain. A 4-category "job strain change" measure exhibited a fairly consistent pattern of associations with work, home and sleep AmBP [77]. Men without job strain at either time ($n = 138$) had the lowest mean AmBP at both times, whereas those with chronic exposure ($n = 15$) had the highest mean AmBP at both times. The two groups whose exposure changed (i.e., crossed-over) during the three-year follow-up period ($n = 17$, $n = 25$) had intermediate levels of BP on both occasions [77].

The association between job strain and AmBP was stronger in the group with chronic exposure than it was in the separate cross-sectional analyses. The chronically exposed group exhibited a consistent 11–12 mm Hg higher systolic and 6–9 mm Hg higher diastolic AmBP than the group unexposed at both times [77].

The effect sizes for cumulative job strain on systolic AmBP at Time 1 and Time 2 are substantial, more than twice the difference between African-Americans and whites in this sample (5.8 mm Hg) and more than the estimated effect of aging 25 years or gaining 50 pounds in weight [77]. These are also clinically significant effect sizes. A 5–6 mm Hg increase in the level of diastolic BP is typically associated with a 20–25% increased risk of CHD [94].

Examining the 3-year change in AmBP between Time 1 and Time 2, those reporting job strain at Time 1 but no job strain at Time 2 ($n = 25$) exhibited a decrease in systolic AmBP of 5.3 mm Hg at work and 4.7 mm Hg at home ($p < 0.05$) [77]. Men in this group also showed a significant decrease in diastolic AmBP of 3.2 mm Hg at work and 3.3 mm Hg at home. These means were adjusted for age, BMI, race/ethnicity, current smoking status, and alcohol consumption status. The decrease in AmBP associated with a decrease in job strain over time suggests that early detection and prevention strategies should be effective.

2.4. *Total impact of psychosocial workplace exposures on CVD risk*

The population attributable risk (PAR%) of CVD due to psychosocial work factors may be substantial. Karasek and Theorell estimated a prevalence of exposure of 15–25% in Sweden and a resulting PAR% of 7–16% for men, depending upon the age group [33]. A relative risk of 2.0 (based on the studies reviewed above) and a prevalence estimate for job strain of 15–25% (a conservative estimate given current economic trends and current European surveys) produces a PAR% of 13–20%. In Denmark, the PAR% for monotonous high paced work (a proxy for job strain) was estimated at 6% for men and 14% for women (based on a RR $= 2$ and prevalence of 6% for men and 16% for women) [51]. However, there are very few studies which examine the combined or synergistic effect of various workplace risk factors.

3. Pathways mediating the association between work stressors and CVD

While the mechanisms by which job stressors act to influence the development of CVD remain to be fully elucidated, at least four possible pathways exist [50]. The first two pathways discussed below involve atherosclerosis and increased risk of cardiac events among vulnerable individuals. Job stressors can also have their effect via a number of standard cardiac risk factors, with blood pressure elevation as a key mechanism. Possible social psychological pathways are reviewed briefly, as well.

3.1. *Atherosclerosis*

Some evidence is provided by an association between low decision latitude and high plasma fibrinogen, suggesting a link with coagulation and, thus, atherosclerosis [95,96]. This pathway is consistent with the association between epinephrine levels and coagulation [33,97,98], for example, the stimulation of platelet adhesiveness by epinephrine. One study of men who had suffered an MI before age 40 indicated more progression of coronary atherosclerosis over five years in those with low job decision latitude than in others [99]. A study of Finnish men showed more rapid progression of carotid atherosclerosis over 4 years in those with high demands and low economic rewards at work than others with low demands and high rewards [56]. Hypertension also contributes to atherosclerosis [100].

3.2. Risk of cardiac events in vulnerable persons

The influence of sympatho-adrenal activity on cardiovascular function in vulnerable individuals includes – e.g., increased myocardial oxygen demand and decreased myocardial oxygen supply that can lead to myocardial ischemia [101], destabilization of the cardiac electrical substrate [102], and increased risk of clot formation and disruption of unstable plaques [100]. Platelet activation and the concentration of fibrinogen (both stress-related) also play a role in acute thrombosis [100]. Job strain may also inhibit anabolic (regenerative) processes which have relevance to the condition of the heart [103,104]. Return to jobs with job strain was found to be associated with increased risk of IHD-related mortality among a series of men who had suffered a first MI before age 45 [105].

3.3. Known CVD risk factors

3.3.1. Hypertension

The strongest evidence for a role for job stressors in the promotion of known CVD risk factors is for hypertension [36]. Growing evidence implicates sympathetic nervous system overactivity in the clustering of hypertension and various atherogenic biochemical abnormalities, together known as the cardiovascular metabolic syndrome (CVM). The CVM includes hypertension, increased total cholesterol, triglycerides and insulin; decreased high-density lipoprotein (HDL) cholesterol; central obesity; insulin resistance and glucose intolerance; and hypercoagulability and reduced fibrinolysis [106,107].

Building on the work of Henry and Stephens [108, 109], Frankenhauser and colleagues confirmed the involvement of two neuroendocrine systems in the stress response – the sympathoadrenal medullary system (which secretes the catecholamines, epinephrine and norepinephrine), and the hypothalamic-pituitary-adrenal cortical system (which secretes corticosteroids such as cortisol). Under demanding conditions where the organism can exert control, i.e., in the face of controllable and predictable stressors, epinephrine levels increase, but cortisol decreases. However, in demanding but low control situations (analogous to "high strain" jobs), both epinephrine and cortisol are elevated and effort with distress is experienced [79,110–113]. Elevated levels of both catecholamines and cortisol appear to have severe consequences for myocardial pathology [114–116]. Cortisol enhances and prolongs the effect of epinephrine [117]. The combination of these hormones appears to promote blood pressure elevation [113], dyslipidemia [117], and the cardiovascular metabolic syndrome [107].

The physiology of the stress response contradicts the standard advice given in stress management programs – that stress depends only on a person's perception of environmental demands. In fact, levels of control available to individuals in the environment is key to the type of stress response elicited. In addition, personal control may exert a positive effect by reducing the duration of the stress response [110]. Repetitive and machine-paced jobs, as well as excessive overtime, tend to prolong "unwinding", the return of neuroendocrine levels to baseline [110,111]. Ambulatory BP studies indicate a "carryover" effect or permanent elevation in which the work, home and sleep BP of "high strain" workers is elevated above levels of other workers [36]. Another obstacle to "unwinding" may be the dual role (the additional responsibility for household and children) that many workers (primarily women) face when they return home [118].

While the precise mechanisms leading from an acute rise in BP to chronic essential hypertension are not fully delineated, the pattern of AmBP findings associated with exposure to job strain seems generally consistent with our present understanding of the phases. These include adrenergic stimulation in the early stages, and later development of structural changes, eventually leading to fixed hypertension. There is also empirical data linking exposure to job strain with increased left ventricular mass index. For an in-depth discussion of these mechanisms as they relate to occupational stressors, see Schwartz et al. [113].

3.3.2. Known risk factors other than hypertension

Research on the association of work stressors with serum cholesterol and behavioral CVD risk factors have produced inconsistent results. Effort-reward imbalance was associated with LDL/HDL cholesterol ratio in several studies [86,119] and with the combined occurrence of hypertension and hyperlipidemia [87]. Some evidence exists for an association of job strain with smoking intensity and cessation [120–123] although null studies have also been reported. In the Work Site Blood

Pressure Study, men who quit smoking had a significantly higher increase in job decision latitude over 3 years than men who did not quit or did not smoke [124]. Job strain has been associated with BMI [125] and skinfold thickness [126], but other studies of job strain and other job stressors have found no association with overweight [120,124,127–129]. Leisure-time physical activity was not associated with job strain, job demands or latitude in two studies [124,128]. However, other studies found sedentary behavior to be associated with low latitude for men and women [120,130] and high job demands for women [130].

3.4. Social psychological mechanisms

The precise role played by personality traits (e.g., Type A behavior, hostility) or emotional states (e.g., anxiety, anger or depression) in the development of hypertension and CVD remains unclear. Current evidence is more consistent for an association with CVD than with hypertension.

3.4.1. Hypertension

In some studies, hypertension has been linked with internalized aggression [131] and with anxiety [132–134], although other studies have failed to find these associations [132,133,135,136]. Various methodological problems have plagued such studies [136], including: 1) anxiety or anger resulting from being diagnosed and labeled with a disease such as hypertension [137,138]; and 2) the inherent difficulty in measuring BP [139]. For example, when BP is measured with the more accurate ambulatory monitor, no association is seen between BP and personality traits or emotional states [136]. What may be necessary is a model which specifies interactions or mediation between environmental stressors and personality characteristics in the development of hypertension [50]. For example, suppressed anger was associated with the prevalence of hypertension in male hourly workers only among those reporting job stressors [140].

3.4.2. CVD

Chronic anxiety may be a mediating factor between social factors such as low SES, unemployment, social isolation, job insecurity and job strain, and CVD. Many emotions "are responses to power and status differentials embedded within social situations" [141, p. 55]. Positive associations have been found between anxiety and job stressors in a number of studies [142–146]. Depression has also been associated prospectively with CHD [147–149], and linked with stressful job characteristics [142,143,150–152]. Type A behavior has been described as "not a set of personality characteristics leading to behavioral and physiologic responses by some invariant process elicited by any environment. Rather, it is seen as the outcome of a set of predispositions interacting with specific types of eliciting situations, including those that are stressful or challenging" [153, p. 924]. The hostility component of Type A may be a risk factor for CHD [154] and some studies have found associations between hostility and job stressors [143,146,155].

3.4.3. Role of job characteristics

Further research is needed to test the hypothesis that job stressors may increase the risk of hypertension and CVD, in part, by shaping personality or by increasing anxiety, anger, hostility or depression. Karasek's job demands-control model describes the adult socialization of personality traits and behavior patterns which occur at work [33,130]. Chronic adaptation to low control-low demand situations ("passive" jobs) can result in reduced self-efficacy, greater external locus of control [156], reduced ability to solve problems or tackle challenges [33,152], and feelings of depression [152] or "learned helplessness" [157]. Conversely, when high job demands are matched with greater authority and skill, more active learning and greater internal locus of control develop. This can enable individuals to develop a broader range of coping strategies [158]. For example, in Sweden, workers whose jobs became more "passive" over six years reported less participation in political and leisure activities. In contrast, workers in jobs which became more "active" participated more in these activities [33, p. 53]. In a US study, evidence was seen for increased intellectual flexibility, non-authoritarianism, capacity to take responsibility for one's actions, and intellectually demanding leisure time after 10 years among those with greater occupational self-direction, a concept similar to decision latitude [159–161].

4. Measuring work stressors

Three main approaches have been used to measure psychosocial work stressors: self-report questionnaires [162], job title averages [163], and observer assessment [164].

Self-report questionnaires tend to be inexpensive, easy to administer, and, when national occupational survey data are available, comparisons can be made between study participants and national averages of job characteristics by job title. Their limitations include the possibility of self-report bias, and difficulties due to low literacy, lack of translation of questions into the participants' native language or other problems of trans-cultural validation. We recommend supplementing generic job stressor questionnaires with questions specific to the occupation (s) and target groups being studied, which are particularly useful for intervention research and for communicating study findings to participants. For study participants with identical job titles and the same employer, the use of self-report measures averaged across that job title may reduce the likelihood of self-report bias.

Job title averages (*imputation of job characteristics scores*) is an approach in which average measures of work stressors (e.g., a mean score on each work stressor scale) are determined for various standard occupation and industry groupings based on population surveys. Subsequently, these work stressor measures are assigned or imputed to individual subjects based on the subjects' reported job occupations. This approach has the advantage of reduced possibility of self report bias, as well as the ability to use the imputed stressor scores in studies that contain information on an individual's occupation, but not on their detailed work characteristics. The limitations of this method include the loss of within-occupation variability in work characteristics, the lack of precision of occupation means for small occupations, and the questionable generalizability of the occupation scores to sub-populations and other time periods.

External assessment of job characteristics has primarily used four techniques: examination of company records; expert assessment of job titles without actual observation of individuals at work; supervisor or coworker assessments; and work site observations by trained observers. These can be time-consuming and expensive to conduct, however, we recommend their use in the following situations: the need to validate self-reports, particularly for job characteristics such as job demands or skill utilization; for studies of health outcomes where self-reports may be inaccurate due to "repressive coping" or "denial", and where "repressive coping" might potentially constitute a causal link in the etiology of the disease (e.g. hypertension, alcohol abuse); in companies with a large number of similar work tasks (e.g., repetitive assembly line jobs), where the sample size can be increased by assigning observational measures to all workers with the same task; and to gather detailed information for job stress intervention studies.

We recommend simultaneously using as many of these approaches as possible. Since self-report questionnaires are the most common technique for assessing job stressors, we provide more detail on these instruments below. We do not describe questionnaires which measure the perception of "stress". Due to adaptation, people facing work stressors may not necessarily report feelings of distress. For example, in the Work Site BP Study, "job strain" was not associated with perceived anxiety or distress [146].

4.1. Occupation-specific versus general measures of psychosocial work environment

One approach to developing job stressor questionnaires has been to ask questions specific to a particular occupation or a workplace, for example, nurses [165], teachers [166] or bus drivers [167–169]. Such measures provide rich, detailed information, especially for intervention efforts [170], when workplace representatives (e.g., management, labor and health professionals) are attempting to identify and change specific features of the work environment associated with ill health. However, since job specific questionnaires cannot be used to compare job stressors across different occupations, an alternative approach has been to measure generic or global job characteristics such as demands, control, and social support, using language general enough to be used across a variety of occupations, e.g., [32,53, 169,171]. This is less useful for intervention studies since questions are more "remote from actual work experiences" [170, p. 373]. However, such a procedure has been essential to the development of theories of job stress, such as the demand-control model and the effort-reward model, which have enabled researchers to document associations between job characteristics and CVD across occupations.

4.2. Measuring job characteristics

Since the 1960s, ". . . a plethora of questionnaires, scales, interview schedules and other stress measurement devices have emerged and evolved" [170, p. 368]. Described briefly below are those questionnaires which have been widely used in studies of CVD to describe working conditions. All of them focus on job characteristics such as psychological demands, control or decision latitude, social support, and job insecurity.

4.2.1. Job Content Questionnaire (JCQ)

The core questions of the JCQ [171,172] are derived from the US Quality of Employment Surveys (QES), administered to nationally representative samples of employed individuals in 1969, 1972 and 1977. Thus, JCQ scale scores for any sample can be compared to national US scale averages by job title, gender and industry code. The JCQ has been widely used in North America, Europe and Japan. The means and standard deviations of scales are very similar and internal consistency tends to be similar across populations (average Cronbach's alpha is 0.73–0.74). For further information: www.uml.edu/Dept/WE/jcq.htm.

4.2.2. Swedish Demand-Control Questionnaire (DCQ)

The Swedish DCQ is a shortened and modified version of the JCQ [81], which has been used in a number of studies [66,67]. It contains six questions assessing decision latitude, compared to nine questions in the JCQ. There is also a social support scale, however, it is more oriented towards the atmosphere in the worksite, while the JCQ social support questions are more objective and instrumental in nature. For further information: Tores.Theorell@ipm.ki.se.

4.2.3. Whitehall Job Characteristics Questionnaire

Researchers conducting the Whitehall II study of British civil servants adapted the JCQ for their study [173] by adding questions on decision authority and changing the response format. For further information: Amanda Nicholson, Department of Epidemiology & Public Health, University College London, 1-19 Torrington Place, London WC1E 6BT. E-mail: amandan@public-health.ucl.ac.uk.

4.2.4. Effort-Reward Imbalance (ERI)

The ERI model emphasizes broader aspects of job control than the JCQ, DCQ or Whitehall questionnaires, including low "job security, career opportunities" (job insecurity, undesirable change, poor promotion prospects, and jobs not "adequately reflecting education" level (status inconsistency)) [34,174]. For further information: Johannes Siegrist, e-mail: siegrist@uni-dusseldorf.de.

4.2.5. Occupational Stress Index (OSI)

The OSI incorporates essential elements of the job demands-control ("job strain") model, as well as other formulations of how stressors lead to CVD, such as features of work in high CV risk occupations [35,169, 175–177]. The OSI reflects a cognitive ergonomic-neurophysiologic approach and includes more specific questions than standard job stressor questionnaires, and thus can be useful as a diagnostic tool for intervention strategies. Versions specific to professional drivers and physicians are available, and versions for teachers, clerical workers, air traffic controllers and production line workers are being developed. For further information: Karen Belkic, Center for Social Epidemiology, Room 202, 1528 6th St., Santa Monica, CA 90401, 310-319-6595, e-mail: kbelkic@hsc.usc.edu.

4.2.6. National Institute for Occupational Safety and Health (NIOSH) Generic Job Stress Instrument

The NIOSH questionnaire contains over 100 questions, including items on cognitive demands, role conflict, role ambiguity, responsibility for people, and threat of violence or injury [178] For further information: Joseph J. Hurrell, Jr., NIOSH Division of Surveillance, Hazard Evaluations and Field Studies, Mail Stop R12, 4676 Columbia Parkway, Cincinnati, OH 45226, 513-841-4428, e-mail: jjh3@cdc.gov.

4.3. Future directions in job stressor measurement

The questionnaires described above have focused, for the most part, on characteristics of individuals' jobs – demands, control, support, and job security. Only occasional questions ask about broader issues such as employee influence over departmental or employer policies or procedures, representative influence through labor organizations, or promotion prospects. Similarly, few questionnaires measure management techniques such as electronic monitoring or piece-rate pay systems, or new systems of work organization, such as lean production, total quality management (TQM), cellular or modular manufacturing, or patient-focused care [41]. These new work systems may have dramatic impacts on task level job characteristics and on employee health by increasing levels of job stressors [41]. In addition to expanding the concept of job control to aspects of work group or organizational policies or procedures (as in the full JCQ or the NIOSH questionnaire) or long-term job security/career opportunities (as in the ERI), the full JCQ also begins to measure aspects of job control exercised collectively [179]. Such collective control, e.g., through a union collective bargaining agreement, may be an important means for employees (particularly lower SES employees) to exercise task control, achieve job security, improve promotion prospects, and minimize undesirable change – and thus reduce health risks due to job stressors. For further details on job stressor measurement, see Landsbergis and Theorell [162].

5. Strategies for prevention and treatment

Given the high prevalence of hypertension and CVD and the evidence concerning work-related hypertension and CVD, the individual clinician could quickly be overwhelmed if he or she alone attempted to treat and prevent these conditions. A public health strategy is required. The National Heart, Lung and Blood Institute (NHLBI) emphasized that "without primary prevention, the hypertension problem would never be solved" and that a "population-wide strategy to prevent blood pressure rise with age and to reduce overall blood pressure levels, even by a little, could affect overall cardiovascular morbidity and mortality as much as or more than that of treating only those with established disease" [180, p. 19]. However, the NHLBI makes no mention of the work environment. In contrast, in the Tokyo Declaration [181, p. 5], experts in the US, Europe and Japan called for a program of "surveillance at individual workplaces and monitoring at national and regional levels in order to identify the extent of work-related stress health problems and to provide baselines against which to evaluate efforts at amelioration. They recommended that workplaces assess both workplace stressors and health outcomes known to result from such exposures . . . on an annual basis".

Based upon this approach, we recommend that workplace screening be used to obtain prevalence data on cardionoxious exposures such as job strain, together with data on relevant cardiovascular outcomes, especially elevated BP [182]. The clinician can play an active public health role in this process, by identifying clusters of workplace-related hypertension as potential "occupational sentinel health events" [183]. In other words, by recognizing workplaces in which there is an unusually high prevalence of hypertension, especially among younger workers, the clinician could help target sites for primary and secondary prevention programs. This pro-active approach is feasible and practical [183]. It was clinicians' observations during mandated cardiovascular examinations of urban mass transit operators that helped lay the basis for investigations on an international scale, demonstrating the unusually high prevalence of hypertension among this occupational group, and prompting efforts to ameliorate exposure to job strain and other cardionoxious conditions.

As part of a public health strategy, we also recommend a team approach which would include clinicians, health educators, occupational health psychologists, ergonomists, epidemiologists and other health professionals to identify high-risk workplaces and occupations, provide clinical care, and design and implement workplace interventions. A model for this approach is the New York State Occupational Health Clinics Network, which utilizes teams of physicians, industrial hygienists, ergonomists, health educators and social workers to integrate direct clinical care with worker and employer education and workplace hazard abatement [184]. Further recommendations for clinical practice, worksite health promotion, work organization interventions, and legal approaches are described below.

5.1. Clinical practice

5.1.1. Assessment

There are few published guidelines available (with the exception of physical activity) for clinicians to make informed recommendations about workplace factors [182]. The first step should be to ascertain whether the current occupation is high risk. Then, the clinician needs to ascertain whether the patient is exposed to any physical, chemical, work schedule or psychosocial CVD risk factors at work, and have any of these been increasing over time? Questionnaires, such as the Job Content Questionnaire [171], can help assess job characteristics and job strain.

5.1.2. Health promotion

Another role for the clinician is counseling patients to reduce their levels of unhealthy behaviors, such as smoking. However, some have found that "despite devotion of substantial time and the use of state-of-the-art methods, that our efforts applied systematically among professional drivers were, at best, only minimally effective, unless there was a concomitant amelioration in stressful working conditions" [183]. Some evidence exists of the effectiveness of work site stress-management interventions on individual outcomes [185–187]. The combination of relaxation and cognitive strategies appears to be the most effective type of individual stress-management intervention [187,188]. However, Ivancevich et al. [189] suggest that 70% of individuals fail to maintain long-term commitment to exercise habits and often revert to their previous lifestyle. While stress management interventions may have positive effects, if employees return to an unchanged work environment and high levels of job stressors, those beneficial effects are likely to be eroded [190].

5.1.3. *Treatment*

While it is established medical practice to place patients on medication for hypertension if BP's measured in a clinic exceed 140/90 mm Hg [191], there are important limitations associated with such treatment – issues of efficacy, side effects and cost [192]. First, lowering BP in clinical studies does not lower future morbidity and mortality to the same level as seen in those with normal blood pressure [180,193]. Large scale studies among mild hypertensives has shown little effect of medical treatment of hypertension on risk of cardiac events [194,195]. Second, drug side effects can have a substantial negative impact on an individual's quality of life and can cause morbidity and mortality as well [196,197]. Third, chronic treatment is associated with substantial cost. All these reasons argue that non-pharmacologic interventions, including workplace modifications, represent a possible therapeutic modality, which needs to be explored in controlled, clinical trials [192].

5.1.4. *Return to work*

Because of the risk of CHD mortality [105] or BP elevation [77] when returning to a workplace with stressors, the clinician can play an important role in suggesting workplace modifications. In the previously cited study of men who had suffered a first MI below age 45, the predictive strength of returning to a high strain job is of similar magnitude to the degree of angiographically-assessed coronary atherosclerosis, and more powerful than left ventricular ejection fraction, a result which remained robust after adjustment for standard risk factors [105]. Advances in cardiovascular therapy (e.g. fibrinolysis, coronary angioplasty, coronary bypass surgery, pacemaker technology, automatic implantable cardioverter-defibrillators and drugs) permit the cardiovascular function of many patients to be restored so as to make returning to work possible. However, work should only be resumed with the cooperation of various parties, including the patient's personal physician, their cardiologist and, the appropriate persons at the workplace to modify job conditions [198].

5.2. *Work site health promotion*

Health educators and behavioral specialists have become increasingly aware of the workplace as an intervention site where social change mechanisms can be mobilized to encourage and support employees to improve their health [199–201]. The workplace has also been recognized as an important social environment that influences health behaviors and risk of disease through company policies and norms [200–202] and through the effects of job characteristics [33,130, 200].

One review of 12 work site health promotion studies conducted between 1978–1995 found "favorable clinical and cost outcomes" and "more recent and more rigorously designed research tends to support rather than refute earlier and less rigorously designed studies" [203, p. 1166]. However, another review noted that a majority of studies did not include a control group or randomly assigned subjects, and most used a short measurement period to determine impact "which may positively bias results by increasing adherence rates", as well as "self-selection bias, partially due to high attrition, which would tend to increase the overall effect of the intervention" [201, p. 434]. Few interventions have "focused on the physical, psychosocial or policy work environment" including job strain. Employees "need to be afforded the flexibility necessary to participate" [203, p. 1166]. Many "programs have emphasized risk-factor reduction strategies (e.g. smoking cessation, stress management, health risk appraisal), but have not integrated disease prevention and safety programs with organizational policies to enhance the physical and social quality of the workplace" [204, p. 1137]. One frequently cited limitation is the tendency for less participation by higher-risk, e.g., lower SES employees [205–207]. The greater effect of job strain on risk of CVD and high blood pressure in lower SES groups implies that workplace health promotion programs need to more fully address the needs of low SES groups and to address occupational sources of stressors and influences on behavior.

5.2.1. *Programs integrating health promotion and environmental interventions*

A number of researchers have recommended integrating workplace health promotion and occupational health, to develop complementary behavioral and environmental interventions [33,199,200,208]. One example of such a program is the WellWorks Project conducted in 24 worksites in Massachusetts [206]. A "significant association was observed between participation in nutrition and [environmental] exposure-related activities, suggesting that participation in programs to reduce exposures to occupational hazards might contribute to blue-collar workers' participation in health promotion activities". In addition, "when workers were aware of change their employer had made to reduce exposures to occupational hazards, they were more likely to participate in both smoking control and nutrition activities" [207, p. 191]. Barriers to participation, such as blue-collar workers' time constraints and job responsibilities, were addressed, for example, through negotiation of time-off for participation in health promotion activities [206].

5.3. *Work organization interventions*

The effectiveness of a limited number of interventions to improve work organization and job design, reduce job stressors, and create a more healthy work organization have been documented [209–211]. For example, an intervention among Swedish civil servants included worker committees which developed and carried out action plans to reduce work stressors. A significant decrease in apolipoprotein B/apolipoprotein AI ratio occurred in the intervention group, but not in the control group. Stimulation from and autonomy over work significantly increased in the intervention group but remained the same in the control group [212]. Another intervention on a difficult inner city bus line in Stockholm was designed to diminish time-pressure and promote traffic flow. There was a significant decline in systolic BP (-10.7 mm Hg) in the intervention group that was greater than in the comparison group (-4.3) [213]. A Swedish field study also showed that systolic BP, heart rate, epinephrine and self-reported tiredness increased significantly during a work shift at a traditional auto assembly line but not at a new and more flexible work organization with small autonomous groups having greater opportunities to influence the pace and content of their work [214]. Albeit of an observational rather than intervention design, the Work Site BP Study indicated that leaving a situation of job strain is associated with a decline of 5.3 mm Hg systolic and 3.2 mm Hg diastolic BP over 3 years [77].

5.4. *Legal approaches to reducing workplace stressors*

The occupational health and safety movement in the US has been able to reduce some workplace hazards through regulation [215] or through collective bargaining [216]. However, efforts to regulate [217] or bargain [216] over work organization and psychosocial stressors such as job strain have met with more limited success, perhaps since employers are reluctant to cede authority in the workplace. A promising development in this area is recent legislation in states such as California and New Jersey, which provide minimum staffing levels and limits on mandatory overtime for health care workers. A valuable model for the US is legislation in Scandinavia, the European Union [218] and Japan [219] which regulate work organization and job stressors as health hazards.

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