Psychophysiological biomarkers of workplace stressors

Tarani Chandola*, Alexandros Heraclides, Meena Kumari

UCL International Institute of Health and Society, UCL Department of Epidemiology and Public Health, University College London, 1-19 Torrington Place, London WC1E 6BT, United Kingdom

**ABSTRACT**

Workplace stressors are associated with greater coronary heart disease risk, although there is debate over the psychophysiological consequences of work stress. This study builds on recent reviews and examines the literature linking work stress with sympatho-adrenal biomarkers (plasma catecholamines and heart rate variability) and HPA axis biomarkers – the post-morning profile of cortisol.

**Methods:** Relevant studies using appropriate search terms were searched using the bibliographic databases PubMed, Embase, Biosys and Toxline. Four studies on plasma catecholamines, 10 studies on heart rate variability, and 16 studies on post-morning cortisol were reviewed.

**Results:** In the majority of studies that examined the association of HRV and work stress, greater reports of work stress is associated with lower heart rate variability. The findings for plasma catecholamines and cortisol secretion are less clear cut and suffer from poorer quality of studies in general.

**Conclusion:** There is evidence that work stress is related to elevated stress responses in terms of sympatho-adrenal and HPA axis biomarkers.

© 2009 Elsevier Ltd. All rights reserved.

---

1. Psychophysiological biomarkers of workplace stressors and health

Exposure to workplace stressors (or “work stress”) increases the risk of heart disease. A recent systematic review concluded that there was moderate evidence that adverse psychosocial working
conditions are a risk factor for ischaemic heart disease among men (Eller et al., 2009). A meta-analysis estimated that there was an average 50% excess risk for CHD among employees with work stress (Kivimaki et al., 2006). The mechanisms leading from exposure to workplace stressors to CHD are hypothesised to be indirect effects through unhealthy behaviours (such as smoking, unhealthy dietary patterns, lack of exercise), as well as direct effects on neuroendocrine stress responses (Chandola et al., 2008).

Activation of these pathways can be quantified using psychophysiological stress biomarkers. However, there is some debate on whether such daily life stressors are associated with elevated neuroendocrine stress responses (Gersten, 2008), especially as many studies report no significant associations and a few report a decreased stress response with work stress.

2. Neuroendocrine pathways linking stress to disease

Stressful stimuli serve to activate neural, neuroendocrine and endocrine pathways. Short term biological responses to stressful stimuli can be adaptive; for example, an increase in the capacity of the blood to clot under stress can serve to reduce blood loss in case of injury. However extreme, frequent or chronic activations of such mechanisms may be detrimental to health. These include changes in the function of two main axes of the stress response: (i) the sympatho-adrenal axis, which includes activation of the sympathetic nervous system leading to changes in peripheral adrenaline and noradrenaline levels; (ii) the hypothalamic-pituitary axis, leading to changes in a wide variety of endocrine factors including cortisol and prolactin.

2.1. Sympatho-adrenal biomarkers

Activation of the sympathetic nervous system can be assessed by measurement of peripheral adrenaline or noradrenaline levels (catecholamines), however these are short acting and short lived molecules and researchers have tended to examine these using integrated methods for example in urine collections, or examine change in these factors in response to an acute stress. Researchers have also examined factors that may reflect the autonomic system function more generally and assess sympathetic or parasympathetic activity. These include measures such as heart rate or heart rate variability, which reflect the balance between sympathetic and parasympathetic activities. Heart rate variability is a measure widely used as a marker of autonomic influences on the heart. This is assessed by power spectral analysis and typical measures include total and low frequency power (relative sympathetic predominance) as well as high frequency power (vagal tone).

2.2. Hypothalamic-pituitary-adrenal axis biomarkers

A primary axis activated upon stress is the hypothalamic-pituitary-adrenal (HPA) axis. Stressful stimuli serve to activate HPA function to cause an increase in peripheral cortisol. Cortisol can effect physiological changes that encompass most of the main organ systems, and help to provide the energetic resources needed to face acute stressors. Cortisol also helps to modulate and contains other components of the physiological stress response (Sapolsky, 2000). Increasingly, HPA-axis researchers are focusing on the marked diurnal rhythm in the release of cortisol, with various elements of this rhythm viewed as essential indicators of HPA-axis functioning. The diurnal cortisol rhythm is typically characterised by high levels upon waking, a substantial (50-60%) increase in cortisol concentration following awakening, peaking at about 30-45 min after awakening (called the cortisol awakening response or CAR), and a subsequent decline over the remainder of the day, reaching a low point or nadir around midnight (Kirschbaum and Hellhammer, 1989). Healthy HPA-axis function is thought to require the presence of strong diurnal patterning. It has been suggested that deviations from the typical diurnal cycle of cortisol may provide valuable information regarding environmental influences on the HPA axis and the role of the HPA axis in disease processes (Carney et al., 2001).

Additional less well considered neuroendocrine pathways that are altered upon stress include increases in prolactin and decreases in testosterone. Additionally, activation of the HPA axis leads to increases in activity in the hypothalamic-pituitary-growth hormone pathway and in the reproductive pathways leading to changes in reproductive hormones in men and women.

3. Defining workplace stressors ("work stress")

There are three main validated models of work stress. The demands/control/support model (Karasek and Theorell, 1990) measures three factors: psychological job demands, decision latitude (or job control) and social support at work. Job strain, a measure of workplace stress, can be derived from the demands/control/support model and posits that people working in jobs that are simultaneously characterised by high demands and low control are at risk of stress-related distress and disease. Iso-strain, a related measure of workplace stress, hypothesises that people experiencing job strain and who are simultaneously socially isolated (experience low work social support) carry even higher risk for disease.

The theoretical approach of the effort–reward imbalance (ERI) model is focused on the notion of social reciprocity where efforts are equalized by respective rewards (Siegrist, 1998). Failed reciprocity resulting from a violation of this norm elicits strong negative emotions and sustained stress. Related to effort–reward imbalance, overcommitment at work is an additional workplace stressor, which may lead to conditions of high effort/low reward.

Organisational justice refers to the extent to which employees perceive workplace procedures, interactions and outcomes to be fair in nature (Elovainio et al., 2002). There are two main components. Relational justice refers to the extent supervisors consider their employees' viewpoint, are able to suppress personal biases, and take steps to deal with subordinates in a fair and truthful manner. Procedural justice involves the fairness of formal decision-making procedures.

4. Recent reviews linking workplace stressors to neuroendocrine responses

There have been two recent reviews on workplace stressors and neuroendocrine responses. One focussed on physiological changes in blood and urine (Hansen et al., 2009) while another focussed on the cortisol awakening response (Chida and Steptoe, 2008). The Hansen et al. (2009) review found 11 studies that linked adverse psychosocial working conditions with urinary catecholamines, while a further four studies showed no association. The review did not find any evidence for an association between work stress and lower levels catecholamines. This review also did not report any studies on work stress and plasma catecholamines.

The Hansen et al. review also concluded that there are no consistent associations between cortisol in serum or urine and the psychosocial working environment. In contrast, the Chida and Steptoe (2008) review concluded there is a positive association between work stress and the cortisol awakening response. The reasons for this discrepancy may partly lie in the nature of the studies reviewed (predominantly urinary cortisol samples for the Hansen et al. review, while the Chida and Steptoe review included saliva samples), and also in the inclusion of differing sampling conditions.
schedules of cortisol reviewed in the Hansen et al. paper. On the other hand, the Chida and Steptoe review explicitly took the diurnal profile of cortisol into account, and only looked the cortisol awakening response (CAR). In relation to cortisol and the importance of the diurnal patterning outlined above, this is probably the stronger study and so their conclusion that work stress is related to CAR is more robust.

Despite these two recent reviews on work stress and neuroendocrine responses, there are few areas not covered in relation to plasma catecholamines, heart rate variability and the diurnal (post-morning) profile of cortisol. These psychophysiological biomarkers will be the subject of review in this paper.

5. Methods

We searched for relevant studies using the bibliographic databases PubMed, Embase, Biosys and Toxline for the period until August 2009. We also scrutinised reference lists from relevant reviews and articles. The search terms used for the sympatho-adrenal biomarkers included: catecholamines, adrenaline, epinephrine, norepinephrine, and heart rate variability, HRV, vagal tone. The search terms for workplace stressors included job stress, work stress, job strain, job control, job demands, work social support, effort–reward imbalance, overcommitment, organizational justice.

The inclusion criteria were papers written in English, with measures of work stress. The exclusion criteria were studies not using validated work stress measures (job demands/control/support/job strain/iso-strain, effort–reward imbalance, organisational justice and some specific professional stress scales). In addition, specific exclusion criteria were used for the catecholamines results (excluding studies with urinary samples) and for the cortisol analysis (excluding CAR only analyses and morning only samples).

The search strategy returned 4 studies on plasma catecholamines, 10 studies on heart rate variability and 16 studies on post-morning cortisol. A quantitative assessment of these studies was not carried out as the measurement protocols of the psychophysiological biomarkers of stress and the work stress exposure vary considerably from study to study. The studies were reviewed in terms of study population, sample size, exposure measurement, study design (whether work stress was measured cross-sectionally or longitudinally) and association. The associations were labelled as “positive” (work stressors were associated with higher levels of the biomarkers), “negative” (work stressors were associated with lower levels of the biomarkers) and “non-significant” (the significance level for the statistical test of association was <0.05).

6. Results (Table 1)

6.1. Sympatho-adrenal biomarkers

6.1.1. Plasma catecholamines

Two out of four studies report a negative association between work stress and plasma catecholamines (Kawaguchi et al., 2007; Wirtz et al., 2008). Two studies report a non-significant association (Nomura et al., 2005; von Kanel et al., 2009), although one of them (von Kanel et al., 2009) reports a marginally positive association (p = 0.06) between overcommitment and noradrenaline. Kawaguchi et al. (2007) assessed work stress (Hurrell and McLaney, 1988) among nurses, and reported greater job control is

<table>
<thead>
<tr>
<th>1st author</th>
<th>Year</th>
<th>Sample</th>
<th>Occupation</th>
<th>Exposure</th>
<th>Study design</th>
<th>Association</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kawaguchi</td>
<td>2007</td>
<td>128f</td>
<td>Nurses</td>
<td>(Low) job control</td>
<td>C</td>
<td>–</td>
</tr>
<tr>
<td>von Kanel</td>
<td>2009</td>
<td>19m/13f</td>
<td>Teachers</td>
<td>ER/OC</td>
<td>L</td>
<td>–</td>
</tr>
<tr>
<td>Nomura</td>
<td>2005</td>
<td>396m</td>
<td>Information technology</td>
<td>Job strain</td>
<td>C</td>
<td>–</td>
</tr>
<tr>
<td>Collins</td>
<td>2005</td>
<td>36m</td>
<td>Population based sample</td>
<td>(Low) job control</td>
<td>L</td>
<td>–</td>
</tr>
<tr>
<td>Hanson</td>
<td>2001</td>
<td>39m/31f</td>
<td>White collar workers</td>
<td>OC</td>
<td>C</td>
<td>–</td>
</tr>
<tr>
<td>Riese</td>
<td>2004</td>
<td>159f</td>
<td>Nurses</td>
<td>Job strain</td>
<td>C</td>
<td>–</td>
</tr>
<tr>
<td>Collins</td>
<td>2005</td>
<td>36m</td>
<td>Population based sample</td>
<td>(Low) job control</td>
<td>L</td>
<td>–</td>
</tr>
<tr>
<td>Hansson</td>
<td>1988</td>
<td>18m</td>
<td>Medical residents/lab technicians</td>
<td>Daily stress inventory</td>
<td>C</td>
<td>–</td>
</tr>
<tr>
<td>Siegist</td>
<td>1997</td>
<td>68m</td>
<td>Middle managers</td>
<td>ERI</td>
<td>C</td>
<td>–</td>
</tr>
<tr>
<td>Evans</td>
<td>2001</td>
<td>40m/53f</td>
<td>Nurses and accountants</td>
<td>(Low) work social support</td>
<td>C</td>
<td>–</td>
</tr>
<tr>
<td>Fujiwara</td>
<td>2004</td>
<td>16f</td>
<td>Nurses</td>
<td>Job strain</td>
<td>C</td>
<td>–</td>
</tr>
<tr>
<td>Steptoe</td>
<td>2000</td>
<td>41m/64f</td>
<td>School teachers</td>
<td>Job strain</td>
<td>C</td>
<td>–</td>
</tr>
<tr>
<td>Evans</td>
<td>2001</td>
<td>40m/53f</td>
<td>Nurses and accountants</td>
<td>(Low) work social support</td>
<td>C</td>
<td>–</td>
</tr>
<tr>
<td>Fujiwara</td>
<td>2004</td>
<td>16f</td>
<td>Nurses</td>
<td>Job strain</td>
<td>C</td>
<td>–</td>
</tr>
<tr>
<td>Steptoe</td>
<td>2000</td>
<td>105m/92f</td>
<td>Civil servants</td>
<td>OC</td>
<td>C</td>
<td>–</td>
</tr>
<tr>
<td>Alderling</td>
<td>2006</td>
<td>181m/384f</td>
<td>Population</td>
<td>Job strain</td>
<td>L</td>
<td>–</td>
</tr>
<tr>
<td>Eyer</td>
<td>1991</td>
<td>28m/55f</td>
<td>Volunteers</td>
<td>ERI</td>
<td>C</td>
<td>–</td>
</tr>
<tr>
<td>Harris</td>
<td>2009</td>
<td>44f</td>
<td>Care workers</td>
<td>(Low) job control</td>
<td>C</td>
<td>–</td>
</tr>
<tr>
<td>Belling</td>
<td>2008</td>
<td>20m/33w</td>
<td>School teachers</td>
<td>ERI/OC</td>
<td>C</td>
<td>–</td>
</tr>
<tr>
<td>Belling</td>
<td>2008</td>
<td>40m/95f</td>
<td>School teachers</td>
<td>ERI</td>
<td>C</td>
<td>–</td>
</tr>
<tr>
<td>Maina</td>
<td>2008</td>
<td>16m/89f</td>
<td>Call centre workers</td>
<td>Job strain</td>
<td>C</td>
<td>–</td>
</tr>
<tr>
<td>Rystedt</td>
<td>2008</td>
<td>53m/24f</td>
<td>White collar workers</td>
<td>Iso-strain</td>
<td>L</td>
<td>–</td>
</tr>
<tr>
<td>Maina</td>
<td>2009</td>
<td>16m/20f</td>
<td>Call centre workers</td>
<td>Job strain</td>
<td>C</td>
<td>–</td>
</tr>
</tbody>
</table>

m: males; f: females; OC: overcommitment; ERI: effort–reward imbalance; C: cross-sectional measure of work stress; L: longitudinal measure of work stress; |: positive association (greater work stress with higher levels of biomarker); —: negative association (greater work stress with lower levels of biomarker); |: non-statistically significant association (at 5% level); *: measured from the NIOSH job stress inventory (Hurrell and McLaney, 1988).
correlated with higher levels of noradrenaline. Workload (job demands) was not associated with catecholamines. Wirtz et al. (2008) showed overcommitment among male volunteers is associated with lower baseline levels of noradrenaline and lower stress reactivity to a stress test. These findings are congruent with previous results showing reduced responsiveness to stress among those with chronic effort–reward imbalance (Siegist et al., 1997). The authors (Wirtz et al., 2008) suggest that overcommitment may lead to an initially heightened stress response, but over time this leads to vital exhaustion (Appels, 1997) and compensatory down-regulation of stress hormone production. However the study (Wirtz et al., 2008) is cross-sectional and cannot evaluate if over-commitment does represent an overtaxing of biological stress responses.

The collection of urine samples is very intensive, invasive and not conducive for large sample sizes so it may be expected that plasma biomarkers are more readily measured in large scale studies. However the plasma catecholamine studies reviewed had small sample sizes. In addition, three studies recruit from single occupational groups such as teachers (von Kanel et al., 2009) and nurses (Kawaguchi et al., 2007). Two of the studies measured workplace stressors using the effort–reward imbalance/overcommitment model (von Kanel et al., 2009; Wirtz et al., 2008), one used the job strain model (Nakamura et al., 2005). Most of the studies were cross-sectional, and only one study (von Kanel et al., 2009) measured changes in work stress (over a 13–27-month period).

This review found no clear association between work stress and plasma levels of catecholamines. The small sample sizes and restricted sample populations make it hard to generalise to other working populations.

6.2. Heart rate variability

Seven of the ten studies reviewed found a negative association between workplace stressors and heart rate variability which suggests work stress reduces vagal activity. Some used the job demands/control/support model to report an association with job strain (Collins et al., 2005; Kang et al., 2004), iso-strain (Chandola et al., 2008) or low job control (Collins et al., 2005; Hemingway et al., 2005). Other studies have found an association with effort–reward imbalance (Hanson et al., 2001; Hintsanen et al., 2007; Vrijkotte et al., 2000). Only one study (van Amelsvoort et al., 2000) reported a positive association job strain and higher heart rate variability. Two studies found no significant associations (Elavainio et al., 2006; Riese et al., 2004) although both reported negative associations between work stress and heart rate variability. Riese et al. (2004) suggest that the effect of job strain on (lower) heart rate variability is less apparent for women compared to men, however this is contradicted by other studies in Table 1 with women workers showing positive associations between work stress and (lower) heart rate variability. Elavainio et al. (2006) reported low perceived justice was also related to an 80% excess risk of reduced high frequency heart rate variability compared to high perceived justice, but this association was not statistically significant.

Unlike the majority of studies on the association between work stress and plasma catecholamines, most of the studies analysing the effect of work stress on heart rate variability do not sample a single occupational group. Furthermore, the sample sizes of these studies tend to be larger, with the Whitehall II civil servants study comprising the largest single study. Three of the studies used longitudinal measures of work stress to ascertain chronic work stress (Chandola et al., 2006; Collins et al., 2005; Riese et al., 2004). The review of studies largely finds a negative association between work stressors and the heart rate variability components. This suggests that workplace stress leads to vagal withdrawal and sympathetic saturation, indicating a prevalence of sympathetic mechanisms leading to cardiac electrical instability (Malik and Camm, 1993).

6.3. HPA axis biomarker: post-morning cortisol levels

There is no clear pattern of association in Table 1. Six studies report positive associations, four studies report negative associations and nine studies report no significant associations.

6.3.1. Reduced cortisol reactivity (negative associations)

In a study of school teachers (Bellingrath et al., 2008; Bellingrath and Kudielka, 2008), highly overcommitted teachers as well as those reporting lower rewards at work showed lower cortisol responses after an acute stress challenge compared to teachers with lower levels of overcommitment and greater rewards. Siegrist et al. (1997) also observed reduced increased cortisol responses in stressed middle managers in terms of ERI, after a stress test. The results from these studies are similar to those from Wirtz et al. (2008) which found overcommitment was associated with reduced stress reactivity. In a study of nurses and accountants (Evans and Steptoe, 2001), work social support was not related to cortisol on work days, but on leisure days, cortisol was lower among individuals reporting low social support. In contrast to the studies cited above (Bellingrath et al., 2008; Bellingrath and Kudielka, 2008; Siegrist et al., 1997; Wirtz et al., 2008), Evans and Steptoe (2001) suggest that cortisol measured during the daytime and evening, and especially during non-work days is not a good marker of psychobiological responses to work. Differences in cortisol output early in the day may be much more sensitive to work and chronic strain (Pruessner et al., 1997).

6.3.2. Increased cortisol reactivity (positive associations)

Six studies found positive associations between work stress and cortisol levels measured in the afternoon or evening. In a longitudinal study of white collar workers (Rystedt et al., 2008), chronic work stress (iso-strain) was associated with higher evening cortisol levels. The authors suggest morning cortisol may be more affected by current levels of job strain, while evening cortisol levels are influenced by chronic psychosocial stressors. This result is in concordance with the findings by Dahlgren et al. (2005) in which evening cortisol was shown to be affected by self reported “stress” levels during working days. In a study of women care workers (Harris et al., 2007), those with lower levels of work stress (having greater job control) had lower cortisol levels in the evening. In a study of healthy volunteers (Eller et al., 2006), men who were overcommitted and reported greater effort–reward imbalance had higher evening levels of cortisol than men reporting less work stress. Two studies from the Whitehall II civil servants study report greater overcommitment (Steptoe et al., 2004) and low job control (Kunz-Ebrecht et al., 2004) among men are associated with elevated cortisol production throughout the day. Three studies reported gender specific analyses: work stressors were associated with higher levels of cortisol during the day among men but not women in these studies. However, other studies with women participants report positive associations between work stressors and cortisol. Hence there is no consistent evidence to suggest that the association of work stress with cortisol reactivity is stronger among men.

It is clear that there are studies that find greater levels of work stress are associated with both lower cortisol reactivity and higher levels of cortisol production throughout the day. It has been speculated that reduced cortisol responses in individuals reporting work stress might be the consequence of a chronic state of stress. However, only three studies in this review actually used longitudinal data to measure chronic work stress and among them only one study (Rystedt et al., 2008) found chronic work stress was
associated with higher evening cortisol levels. There was no evidence that work stress measured longitudinally ("chronic work stress") was associated with lower cortisol reactivity.

Overall, most of the studies reviewed suffered from the same limitations as the review for plasma catecholamines – most were cross-sectional, with small sample sizes and restricted sample populations making it hard to generalise to other working populations. The lack of a clear pattern in the results may arise primarily from these limitations.

6.4. Workplace stress and other biomarkers

The review by Hansen et al. (2009) also examined associations between work stressors and testosterone and prolactin. It found eight studies showing negative associations between work stressors and testosterone, while a further three found non-significant associations. Out of 17 studies on work stressors and prolactin, 9 studies reported positive associations, 4 studies reported negative associations and a further 4 studies reported no significant associations.

Oxidative DNA damage, measured through urinary concentrations of 8-hydroxy-2′-deoxyguanosine (8-OHdG), has been associated with organisational injustice among men and job strain among women (Inoue et al., 2009). In an experiment, the group that received no (vs. some) rewards (effort–reward imbalance) had hyperactivations in the medial prefrontal, anterior cingulate and dorsolateral prefrontal cortex measured through fMRI scans (Siegrist et al., 2005). This indicates a compromised ability of adapting brain activation among those suffering from chronic social reward frustration.

7. Discussion

In this review, we find evidence that work stressors are associated with increased levels of catecholamines (particularly from urinary samples), lower levels of heart rate variability, a higher heart rate and lower levels of testosterone (see Fig. 1). Thus there is evidence that work stressors are related to elevated stress responses in terms of sympatho-adrenal and HPA axis biomarkers.

Our review of the studies available suggests that measurement of biomarkers of work stress tends to be limited to small focussed studies rather than large scale epidemiological cohorts. Studies are also largely cross-sectional, with few studies on longitudinal measurements of work based stress and autonomic or neuroendocrine function. Despite measuring work stress only cross-sectionally, a number of studies discuss how chronic work stress leads to blunted stress reactivity profiles. This had led to the interpretation of reduced levels of stress biomarkers with work stress as evidence of the effect of chronic work stress on physiological stress responses. However, only longitudinal studies would be able to examine the suggested bi-modal response of these outcomes to work based stressors; whether work stress leads to an initial activation followed by exhaustion of the pathways (Appels, 1997). Furthermore, even longitudinal assessment of work stressors may not necessarily reveal exhaustion if the assessment period of work stress has not been long enough.

We did not conduct a formal meta-analysis of the literature because of the wide heterogeneity in the measurement of the work stress exposure and stress response. For example, although heart rate variability had the most consistent associations in the literature, the methodology varied considerably between studies. For example, Chandola et al. (2008) measured heart rate variability for 15 min during a clinical visit and found a positive association between job strain and lower HRV while Riese et al. (2004) measured heart rate variability for 24 h on two occasions and failed to find an association. Measurement decisions are based on many factors including participant burden, size of study, but harmonisation of methodologies across a number of studies may serve to reduce imprecision in findings.

We were careful to distinguish the association of the stressor, in this case work based stress from the stress response in our review. This review did not consider burnout, anxiety (Kawachi et al., 1995) and panic disorder (Yeragani et al., 1993) as within the remit of these measures do not distinguish the stress generating working conditions from the psychological stress response. We also did not consider inflammatory markers as within the remit of this review even though they may be important mediators between stressors and health. This is because we aimed to examine ‘upstream’ markers that may mediate the stressor–health relationship. In the allostatic load paradigm, these may be considered ‘primary mediators’ in the cascade (McEwen and Seeman, 1999). Inflammatory markers represent secondary mediators in the cascade. Additionally, inflammatory marker levels are substantially influenced by adiposity as adipocytokines release inflammatory markers (Mohamed-Ali et al., 2007) contributing up to one third of circulating levels.

Most of the studies reviewed used either the job strain or the effort–reward imbalance models to measure work place stressors. Although these models differ in their theoretical basis, they also measure overlapping concepts (especially in relation to job demands and efforts at work). The review did not find any systematic association of either model with specific biomarkers, suggesting that physiological stress reactions to work stress are basically the same irrespective of the source of stressors.

Our review suggests that work based stress measures are consistently associated with alterations in the autonomic nervous system such that there is an apparent alteration in sympathetic parasympathetic balance. These changes in autonomic function have been associated with adverse health outcomes. Delayed heart rate recovery and lower cardiac autonomic reactivity (heart rate, pre-ejection period, and heart rate variability) were prospectively associated with higher carotid atherosclerosis over a 2-year period (Heponiemi et al., 2007). In 1999 participants of the Whitehall II study, measures of autonomic function are associated with some measures of work based stress and in prospective analyses with measures of health, in particular with obesity, blood pressure and cholesterol (Britton et al., 2007). This adds to the plausibility that work stress leads to coronary heart disease partly through activation of the physiological stress responses reviewed in this study.

The association of cortisol secretion with health outcomes is currently unclear with no consistent evidence from large scale
prospective surveys of an independent association with health outcomes. Currently there is poor empirical evidence that the cortisol awakening response is associated with clinical end points while there is evidence that slope in diurnal cortisol secretion is predictive of increased mortality in patient populations (Sephton et al., 2000).

8. Limitations

This review has several limitations. A limitation inherent in most reviews is that they are restricted to the evaluation of results in published articles. Authors are more likely to submit and editors more likely to accept papers with positive rather than null or negative findings, which may lead to a positive publication bias. Another limitation is the inconsistent use of psychophysiological biomarkers between studies, leading to over-representation of some biomarkers (e.g. cortisol) and very limited use of others (e.g. DHEA). Also, the cortisol response patterns vary as a function of stressor, and therefore there is no single method for assigning reactivity and recovery to all studies of cortisol in response to acute stress (Dickerson and Kemeny, 2004). The variety in exposure and outcomes limits the ability to formal statistical examination of the literature. Due to these limitations, as well as the small number of studies identified for some biomarkers, the findings for specific biomarkers should be interpreted with caution.

9. Conclusion

In this review, we find that in the majority of studies that have examined the association of HRV and work based stress, greater reports of work stress is associated with lower heart rate variability. The findings for plasma catecholamines and cortisol secretion are less clear cut and suffer from poorer quality of studies in general. Taken in conjunction with recent reviews (Chida and Steptoe, 2009; Hansen et al., 2009), there is evidence that work stressors are related to elevated stress responses in terms of sympato-adrenal and HPA axis biomarkers.

Acknowledgements

Tarani Chandola and Meena Kumari are supported by the Economic and Social Research Council International Centre for Life Course Studies in Society and Health (RES-596-28-0001). They are also work on the Whitehall II study. The Whitehall II study has been supported by grants from the Medical Research Council; Economic and Social Research Council; British Heart Foundation; Health and Safety Executive; Department of Health; National Heart Lung and Blood Institute (HL63610), US, NIHR: National Institute on Aging (AG13196), US, NIH: Agency for Health Care Policy Research (HS68516); and the John D. and Catherine T. MacArthur Foundation Research Networks on Successful Midlife Development and Socio-economic Status and Health.

References


