

Ambulatory physiological assessment: an ergonomic approach to the dynamic work environment and temporal variability in heart rate variability, blood pressure and the cortisol awakening response.

Thomas George Campbell

November 2014

A thesis submitted in partial fulfilment of the requirements of Edinburgh Napier University for the award of Doctor of Philosophy

Declaration

It is hereby declared that this thesis and the research work upon which it is based were conducted by the author, Thomas George Campbell.

Thomas George Campbell

“Variability is the law of life, and as no two faces are the same, so no two bodies are alike, and no two individuals react alike and behave alike” (Sir William Osler, 1849-1919)

Acknowledgements

Firstly, I must thank Professor Richard Davison for igniting my enthusiasm for this topic and for directing me in the early stages of this research. I would also like to extend my profound thanks to Professor Greg Atkinson for his invaluable statistical expertise and to my supervisor, Dr Tony Westbury, for his remarkable breadth of knowledge and encouragement.

A special thanks to my director of studies, Dr Geraint Florida-James, for his guidance, for knowing just how much pressure to apply at every stage of this journey, for his unique ability to simultaneously praise and admonish, and, not least, for reminding me of the old adage, *work hard – play hard*.

My eternal gratitude goes to my parents for their unwavering love and support. Also, for reading to me as a child - he's a powerful force that "Littlenose". Additional thanks to my Mum for proof-reading endless drafts of this thesis; there's definitely a scientist in there somewhere. Not to forget the rest of the Campbell clan who have all been there for me in one way or another.

I also would like to thank all my colleagues in the Centre for Learning and Study Support for allowing me the flexibility to pursue my real interest. Thanks also the Rodden Trust for providing much needed financial support.

Lastly to my beautiful wife, without whom I may never have summoned the courage to take the first step on this journey. To Amy, all my thanks and love.

Abstract

Aim: The aim of this thesis was to investigate the psychophysiological response to the dynamic working environment within a cohort of higher education employees via ambulatory assessment of psychosocial and physiological measures.

Methods: Data was collected from two observational studies. Study one employed a cross-sectional design to investigate relationships between work-related psychosocial hazard, work-time heart rate variability, blood pressure, and the cortisol awakening response. Consideration was given to occupation type and acute work-related demand. Study two, a single-subject case study, employed an experience sampling methodology to perform a 24 hour assessment over 21 days. Workload, affect and demand were sampled during working hours, while heart rate variability and physical activity were continually sampled (24 hours), with salivary cortisol, being sampled at 3 time points during the awakening period. This study also investigated some of the methodological issues associated with ambulatory assessment of both heart rate variability and the cortisol awakening response.

Findings: Chronic work-related demand was found to be positively associated with sympathetic dominance of the autonomic nervous system. Acute work-related demand was associated with ambulatory heart rate variability during work time and evening time whilst the rise in salivary free cortisol over the immediate post awakening period varies according to acute anticipatory demand and prior day's workload. Substantial intra--individual variation in both the cortisol awakening response and ambulatory heart variability was found to

occur across work-days. Work time activity levels accounted for little of the variation in ambulatory heart rate variability and blood pressure. The cortisol awakening response was associated with both heart rate variability and nocturnal movement in the latter stage of sleep.

Conclusion: Attending to the psychophysiological response to work at the individual level by means of ambulatory assessment appears to provide a useful means of assessing the balance between employee and environment. This could have significant implications for work design, employee selection and targeting of workplace interventions.

TABLE OF CONTENTS:

Chapter 1: Introduction.....	1
1.1 Biopsychosocial Model of Job Strain	3
1.2. Assessment of Occupational Strain.....	6
1.2.1. The Job-Demand-Control Model(s).....	7
1.2.2. The Effort-Reward-Imbalance model	10
1.3. Questionnaire based assessment.....	11
1.3.1. The Work Ability Index.....	12
1.3.2. The HSE Management Standards Indicator Tool	14
1.4. Alternative methods of assessing work strain	16
1.4.1 Ambulatory assessment.....	17
1.4.2 Ambulatory psychosocial assessment.....	17
1.4.3 Ambulatory blood pressure.....	20
1.4.4 Heart rate variability.....	21
1.4.5 Assessment of hypothalamic pituitary adrenal function: salivary free cortisol	26
1.5. The intra-individuality of stress reactivity.....	29
 Chapter 2: Literature Review.....	 37
2.1 Introduction	38
2.2 Demand Control and Effort Reward Imbalance Models.....	38
2.3 The Work Ability Index and Management Standards.....	42
2.4. Ambulatory blood pressure and work-related strain.....	46
2.5 Assessment of psychosocial strain via heart rate variability.....	51

2.6. Assessment of work-related psychosocial strain via the cortisol awakening response.....	54
2.7. Methodological considerations for sampling the cortisol awakening Response.....	57
2.8. The dynamic workplace and inter-individual variation.....	70
2.9. Summary of review and gaps in the literature.....	73
2.9.1. Summary of literature review.....	73
2.9.2 Gaps in the existing literature.....	75
2.10. Aims and objectives.....	77
 Chapter 3: General Methods	 78
3.1 Introduction	78
3.2 Participant Recruitment	78
3.2.1. Study one.....	78
3.2.2. Study two.....	80
3.3 Equipment.....	81
3.3.1 Cardiotens monitor and software	81
3.3.2 Actiheart monitor and software.....	81
3.3.3 Medication event monitoring system.....	84
3.3.4 Salivette collection system.....	84
3.3.5 Salivary cortisol enzyme immunoassay.....	85
3.3.6 The Work Ability Index.....	85
3.3.7 The HSE Management Standards Indicator Tool.....	86
3.3.8 The Positive and Negative Affect Schedule.....	87

3.3.9 Visual analogue scale.....	88
3.3.10 Workload questionnaire.....	88
3.4 Procedures	89
3.4.1 Salivary cortisol sampling and analysis.....	89
3.4.2 Ambulatory Monitoring.....	92
3.4.3 Signal contingent experience sampling.....	93
3.4.4 Assessment of awakening and sampling times.....	94
3.5 Data processing and statistical analyses	97
3.5.1 Questionnaire-based data.....	97
3.5.2 Statistical analyses.....	98
Chapter 4. Cardiovascular and autonomic response to psychosocial hazard exposure amongst higher education employees: the role of acute demand	100
4.1 Introduction.....	101
4.2 Methods.....	104
4.3 Results.....	105
4.3.1. Questionnaire data.....	106
4.3.2. Physiological data.....	107
4.4 Discussion.....	110
Chapter 5. Variation in the cortisol awakening response in higher education employees according to acute and chronic work-related psychosocial factors	117
5.1 Introduction.....	118
5.2 Methods.....	120

5.3 Results.....	121
5.4 Discussion.....	127
Chapter 6. A single-subject investigation of temporal variation in heart rate variability and the cortisol awakening response with respect to acute work-related demand	137
6.1 Introduction.....	138
6.2 Methods.....	142
6.3 Results.....	144
6.4 Discussion.....	158
Chapter 7. Ambulatory monitoring of blood pressure and heart rate variability: the influence of concurrent work-related physical activity	167
7.1 Introduction	168
7.2 Methods.....	174
7.3 Results.....	176
7.4 Discussion.....	182
Chapter 8. An intra-individual investigation into the cortisol awakening response: associations with heart rate variability and sleep-related factors	191
8.1 Introduction.....	192
8.2. Methods.....	197
8.3. Results.....	197
8.4. Discussion.....	201
Chapter 9. General Discussion.....	208
9.1 Discussion of key findings.....	210
9.2 Recommendations for future work.....	217

9.3 Limitations.....	219
REFERENCES	221
APPENDICES.....	273
Appendix I. Application to ethics committee (study one).....	274
Appendix II. Application to ethics committee (study two).....	280
Appendix III. The Work Ability Index.....	285
Appendix IV. HSE Management Standards Indicator Tool.....	287
Appendix V. Positive and Negative Affect Schedule.....	291
Appendix VI. Visual analogue scale (acute demand).....	292
Appendix VII. Daily workload questionnaire.....	303

LIST OF FIGURES

Chapter 3:

Figure 3.1. Cardiotens monitor.....	81
Figure 3.2. Example of Cardiovisions output.....	82
Figure 3.3 The Actiheart monitor	83
Figure 3.4. Typical Actiheart placement.....	83
Figure 3.5. Medication event monitoring system.....	84
Figure 3.6. Saliva swab and storage tube	85
Figure 3.7. Plate layout for salivary cortisol assay.....	91
Figure 3.8 Area under the curve with respect to increase.....	92
Figure 3.9 Fully instrumented participant.....	95

Chapter 5:

Figure 5.1. Mean values for salivary free cortisol by sample time	122
Figure 5.2. Average workday and weekend awakening cortisol.....	123
Figure 5.3. Awakening cortisol response by day	124
Figure 5.4. Awakening cortisol response according to occupation.....	125

Chapter 6:

Figure 6.1. Day-to-day variation in daytime activity and heart rate variability	148
Figure 6.2. Day-to-day variation in evening activity and heart rate variability	149
Figure 6.3. Day-to-day variation in nocturnal activity and heart rate variability	150
Figure 6.4. Mean cortisol awakening response over all study days	152
Figure 6.5. Day-to-day variation in awakening cortisol response	152
Figure 6.6. Cortisol awakening response according to study day	153

Chapter 7:

Figure 7.1. Minute-by-minute variation in activity, heart rate and
heart rate variability over single 30 minute epoch181

Chapter 8:

Figure 8.1. Awakening times for all 21 study days.....198

LIST OF TABLES

Chapter 2.

Table 2.1. Recent publications on the cortisol awakening response.....	61
------------------------------------------------------------------------	----

Chapter 4.

Table 4.1. A comparison of mean Management Standards scores with benchmark data	106
Table 4.2. Self-reported acute demand by occupation and self-reported chronic psychosocial demand	107
Table 4.3. Ambulatory data according to acute demand presented by occupational group	108
Table 4.4. Correlations between HSEMS and Heart Rate Variability ...	109

Chapter 5.

Table 5.1. Mean self-reported salivary cortisol sampling times by day	122
Table 5.2. Associations between questionnaire data and awakening salivary cortisol	121

Chapter 6.

Table 6.1. Psychosocial work-related characteristics	144
Table 6.2. Associations between questionnaire measures	145
Table 6.3. Physiological and motility data according to time of day	146
Table 6.4. Daytime physiological and motility data according to characteristics of measurement day	147
Table 6.5. Sleep and sampling-related measures	151
Table 6.6. Relationship between questionnaire responses and awakening cortisol	154
Table 6.7. Associations between prior day's HRV and awakening cortisol	155

Table 6.8. Associations between psychosocial and physiological variables	157
Chapter 7:	
Table 7.1. Mean daily activity levels, heart rates and blood pressures	176
Table 7.2. Within-subjects associations between activity and heart rate variability/blood pressure	177
Table 7.3. Mean work-time activity and heart rate variability (single participant)	178
Table 7.4. Associations between work-time activity and heart rate variability (single participant)	179
Table 7.5. Associations between HRV and activity according to epoch length	180
Chapter 8:	
Table 8.1 Mean values for activity, heart rate and heart rate variability over pre and post awakening periods	198
Table 8.2 Associations between sleep-related variables and salivary free cortisol over the awakening period	199
Table 8.3. Associations between heart rate variability and the cortisol awakening response over the pre and post awakening period.....	200

CHAPTER 1. Introduction

1. INTRODUCTION

The nature of work within Western industrial countries has undergone significant changes since the 1970's (Tausig *et al.*, 2004) with jobs being increasingly characterised by demands of a mental and emotional, rather than physical nature, resulting in greater levels of psychosocial workload (De Jonge & Kompier, 1997; Siegrist, 2008). A concurrent increase in the number of non-permanent employment contracts, and non-secure jobs (Guest, 2004; László *et al.*, 2010), has occurred as a consequence of globalisation, deregulation of labour markets, and increased competition, which has further increased the prevalence of psychosocial strain in the workplace (Nübling *et al.*, 2006). Additionally, the United Kingdom, in common with many developed countries, is faced with the challenge of ensuring economic sustainability, despite a population demographic which is leading to increased dependency ratios, and a resultant requirement for greater welfare expenditure (Anderson, 2008). Government policies are being implemented in an attempt to achieve a better balance between the number of employed individuals and dependents, by increasing the state pension age for both men and women, and the number of older workers is certainly increasing throughout Europe, with an 8% increase in the numbers of men and a 9% increase in women aged 55-64 in employment between 2000 and 2008 (European Commission, 2009). However, as a result of decrements in cognitive processing that occur with advancing age, the psychological demands of work may exert higher levels of strain upon older workers (Shultz *et al.*, 2010).

A relationship between work strain and illness has been known to exist since Hinkle and Wolf (1958) reported that rates of illness amongst telephone operators were significantly higher during periods characterised by excessive demands, or frustrations, than at other times. Given the increasingly psychosocial nature of work it is unsurprising that work strain often manifests as psychological dysfunction, and can lead to the development of psychosomatic and cardiovascular diseases (De Jonge & Kompier, 1997). The results of a large scale longitudinal investigation of the effects of psychosocial hazard at work found long term exposure to work strain to be a significant risk factor for cardiovascular disease mortality (Johnson *et al.*, 1996). Exposure to permanent work stress has been found to double the risk of an initial acute myocardial infarction (Rosengren *et al.*, 2004) and is also associated with an increased risk of recurrent coronary heart disease following an initial myocardial infarction (Aboa-Éboulé *et al.*, 2007). Furthermore, working 3 to 4 hours overtime per day increases the risk of coronary heart disease by more than 50% (Virtanen *et al.*, 2010). A recent review (Ho *et al.*, 2010) found that the evidence for the involvement of psychosocial stress upon the development and progression of coronary heart disease is both consistent and convincing. Exposure to psychosocial strain at work is also predictive of general sickness absence (Niedhammer *et al.*, 1998).

1.1 BIOPSYCHOSOCIAL MODEL OF OCCUPATIONAL STRESS

Frankenhaeuser (1991) devised a model of psychosocial stress which considers instances of both overload and underload to result in the experience of psychosocial stress. Overload occurs where situational demands exceed the

ability of an individual to cope with the demand whereas underload occurs where there is insufficient demand to provide an element of challenge to an individual. The biopsychosocial model of job stress (Merlin and Lindberg, 1997) asserts that both overload and underload can elicit physiological responses, such as cortisol and catecholamine secretion. Additionally, the model allows for the incorporation of demands which occur outside of the work realm e.g. childcare, household duties, claiming that these affect the ability of an individual to recover from work strain. Therefore, the cumulative effects of work and non-work demands determine the physiological response of an individual.

Both the autonomic nervous system and the hypothalamic-pituitary-adrenal axis are fundamental to the maintenance of homeostasis during exposure to stressors (Miller & O'Callaghan, 2002; Kudielka & Kirschbaum, 2005; Brotman *et al.*, 2007; Ulrich-Lai & Herman, 2009). The hypothalamic-pituitary-adrenal axis responds to stress by releasing corticotropin releasing hormone from the hypothalamus, which causes the pituitary gland to secrete adrenocorticotrophic hormone, in turn stimulating the adrenal gland to release glucocorticoids; primarily cortisol in humans. Glucocorticoids elevate blood glucose, providing the body with the energy necessary to meet the increased metabolic demands of a stressful situation (Miller & O'Callaghan, 2002). However, an additional role of glucocorticoids is to act within a negative feedback loop, where cortisol inhibits the production of corticotrophin-releasing hormone to suppress the stress response, minimizing the duration of tissue exposure to glucocorticoids and limiting the catabolic and immunosuppressive effects of these hormones (Tsigos

& Chrousos, 2002; Webster & Glaser, 2008). Levels of circulating cortisol can, therefore, provide an indirect measurement of stress exposure. Cortisol is also known to exert an influence upon the sympathetic nervous system (Kudielka & Kirschbaum, 2005; Thayer & Sternberg, 2006). During exposure to stress, the sympathoadrenal system increases the secretion of the catecholamines epinephrine and norepinephrine from the adrenal glands (Padgett & Glaser, 2003). These hormones influence the functioning of the cardiovascular system and elicit alterations to both heart rate and blood pressure (Cohen *et al.*, 1997). The physiological mechanisms of the stress response, therefore, provide both endocrine and cardiovascular markers, which are capable of elucidating the presence of strain.

Reactivity of the hypothalamic-pituitary adrenal axis and the autonomic nervous system are known to demonstrate a degree of synchronicity during exposure to stressors, with numerous studies reporting upon associations between indices of hypothalamic-pituitary adrenal activity, and cardiovascular indicators of autonomic functioning. Certainly, individuals who demonstrate a high cardiovascular reactivity also show the greatest change in endocrine response (Sgoutas-Emch *et al.*, 1994; Cacioppo *et al.*, 1995; Looser *et al.*, 2010). Significantly, in terms of the potential for measures of cardiovascular and endocrine reactivity to predict the future risk of disease and illness, there is also evidence that individual reactivity of the immune system is inter-correlated with both the hypothalamic-pituitary adrenal axis (Cohen *et al.*, 2000; Cohen *et al.*, 2003) and the autonomic nervous system (Herbert *et al.*, 1994; Cohen *et al.*,

2000; Larson *et al.*, 2001; Cohen *et al.*, 2003) providing further support for the existence of a unified stress response. More specifically, it appears to be the sympathetic component of the autonomic nervous system, which is associated with immunologic response. Indeed it has been claimed that the sympathetic nervous system actually moderates the immune response to stress (Herbert *et al.*, 1994). Therefore, assessing the functioning of the sympathetic nervous system may provide an indirect assessment of immunologic functioning. However, a recent review, (Cohen *et al.*, 2003) reported that the congruence of differing stress responses involves a complex relationship, and that only certain immune responses were concordant with cardiovascular and endocrine responses to stress. There may therefore be various types of unified stress responses, which reflect differing sources of immune regulation.

1.2 ASSESSMENT OF OCCUPATIONAL STRAIN

Maintaining, or promoting, the work ability of employees presents a significant challenge for occupational health professionals and employers. However, it is becoming increasingly evident that investments in employee well-being correlate to profitability (Chapman, 2005), providing a favourable synthesis between the moral obligation to look after employees' well-being and the need, or desire, for financial success. Therefore, having the ability to accurately assess the capacity of employees to cope with the various demands of their jobs, in order to target the implementation of interventions is potentially of significant benefit to employers and employees alike. The complex, multifactorial nature of the interaction between work-related environmental and psychosocial factors, and

their effect upon individual well-being has prompted the development of theoretical models in order to attempt to identify and quantify common core determinants of work-related strain. The two most influential and extensively used models are the job-demand-control model (Karasek, 1979) and the effort-reward imbalance model (Siegrist *et al.*, 1986).

1.2.1 The Job-Demand-Control Model(s)

The original job-demand-control model (Karasek, 1979) postulates that the degree of job strain experienced by an individual is determined by the interaction between workplace demands, and the degree of control that employees exert over their daily working practices. Demands are generally defined as mental and physical workloads, and time pressure, whilst control can be conceptualised as being the aggregate of both skill discretion and decision autonomy (De Bruin & Taylor, 2006). The job-demand-control model contains two main hypotheses, which support the premise that exposure to high demands can result in positive or negative outcomes, with control acting as a moderating variable or buffer: the strain hypothesis asserts that the combination of high demands and low control lead to job strain, whilst the interaction hypothesis maintains that high demands accompanied with a high level of control increases motivation, learning, and personal development. Accordingly, increases in job demands should not result in psychological strain provided that employees have sufficient autonomy over how to meet these demands (Wall *et al.*, 1996).

Despite occupying a prominent position within the field of occupational health, the overly general nature of the job-demand-control model has led to criticism regarding its inability to adequately account for the multidimensionality of different job demands and factors affecting perceived control (De Jonge *et al.*, 1999; Sundin *et al.*, 2008; Bakker *et al.*, 2010). This conceptual weakness was emphasised by Sparks & Cooper (1999) who reported that, in addition to work control, six distinct sources of work pressure, namely; work control, career, organizational climate and factors in the job, home/work interface, organizational role and relationships were all associated with physical and mental ill-health, supporting the need for a wider range of stressors to be considered in work strain research. They also found that the correlation between the seven independent variables and mental and physical health differed by occupation.

The need for more job specific models of job-strain has been certainly been demonstrated within care workers, who are subject to very specific physical, psychological and emotional demands. Jourdain and Chênevert (2010) found that in a cohort of nurses, demands were the most important determinants of emotional exhaustion whilst resources predict depersonalization, both of which are associated with intent to leave the nursing profession. In a review of 212 studies De Jonge *et al.* (1999) reported that various combinations of job autonomy and psychological, physical, and emotional demands differentially predict the outcome variables of job satisfaction, emotional exhaustion and psychosomatic health complaints amongst health care workers. More recently, De Jonge *et al.* (2010) found that using measures of demand and control with a

greater job related specificity for health workers supports the interaction hypothesis of the job demand control model and predicts well-being two years later.

Karasek himself has recently acknowledged the limitations of the original job-demand-control model and the need to revise the model to better accommodate the variety of complex work and social structures (Karasek, 2008), and several models have already been proposed to augment the initial concept. Johnson & Hall (1988) expanded upon the job-demand-control model by incorporating support as an additional dimension to create the job-demand-control-support model. The fundamental hypothesis of the job-demand-control-support model, the iso-strain hypothesis, predicts that the combination of high demands, low control, and low support from peers and supervisors, produces the greatest strain and risk of experiencing negative psychological and physical health outcomes. However the model also predicts that support has the ability to buffer the effects of demand and control.

The job-demand-resources model (Demerouti *et al.*, 2001) goes a step further by advocating that resources should not be limited to control and support, with the resources dimension of the model encompassing any physical, social, or organisational components of a job that have the potential to: reduce the job demands and associated costs; facilitate the achievement of work goals, or; simulate personal growth, learning, or development (Bakker *et al.*, 2010). The second premise of the job-demand-resources model is that there are dual

psychological processes that either lead to job strain or job motivation (Bakker *et al.*, 2007). The health impairment process is based on the belief that poorly designed jobs or chronic job demands exhaust employees' mental and physical resources leading to a depletion of energy and ultimately to poor health. Bakker *et al.* (2007) claim that environmental demands require employees to implement performance-protection strategies via enhanced sympathetic activation of the autonomic nervous system or through greater active coping. The alternative process asserts that job resources have the potential to motivate employees, through both intrinsic and extrinsic processes, which leads to high work engagement (Bakker *et al.*, 2007). Job resources are believed to buffer the effect of job demands, which is fundamentally consistent with the original model (Karasek, 1979). Schaufeli *et al.* (2009) found support for both processes, as increased demands and reduced resources predicted burnout amongst a cohort of telecom workers, whilst engagement was negatively associated with sickness absence. Bakker *et al.* (2003) also found that demands predicted health problems and sickness absence, and that resources predicted levels of engagement amongst call centre staff, supporting the concept of the dual process. However, an important distinction between the two models is that the job-demand-resources model asserts that several different buffers may act upon several different demands.

1.2.2. The Effort-Reward-Imbalance Model

In a departure from the aforementioned models, the effort-reward-imbalance model, which was initially devised to help predict and explain cardiovascular

outcomes (Siegrist *et al.*, 1986), focuses upon the dimension of reward, rather than resources, and asserts that a reciprocal relationship exists between the efforts invested in work and the rewards, which are received in return. Whilst efforts can be considered to be largely interchangeable with demands, rewards may take the form of money, job security, career opportunities, and self-esteem, and the model therefore encompasses both extrinsic and intrinsic characteristics. The basic premise of the effort-reward-imbalance model is that where an imbalance in this relationship occurs, with efforts exceeding rewards, emotional distress is experienced, resulting in activation of both the sympathetic-adrenomedullary and the hypothalamic-pituitary-adrenal systems (Siegrist *et al.* 1986). A prolonged deficiency in the reciprocity of efforts and rewards is believed to increase susceptibility to ill health as a result of the stress response (Siegrist *et al.*, 2004). A second assumption of the effort reward imbalance model is that high levels of over-commitment/need for control may increase the risk of poor health (Van Vegchel *et al.*, 2005). The final hypothesis of the model asserts that employees experiencing an effort-reward imbalance, coupled with high over-commitment, have an even greater risk of poor health.

1.3. QUESTIONNAIRE BASED ASSESSMENT TOOLS

There exists an abundance of tools specifically intended for assessment of occupational strain; a review by the UK Health and Safety Executive (HSE, 2001) identified 26 such measures. However, the focus of this section is upon two specific assessment tools: the Work Ability Index (Ilmarinen, 2007) and the Health and Safety Management Standards Indicator Tool (Health and Safety Executive,

2005). The rationale for concentrating upon these two is based upon the relative importance afforded to their use in practice and as research tools. Presently, the Health and Safety Management Standards is currently advocated for use in the workplace by the Health and Safety Executive. However, this is a relatively recent approach which has received limited attention within the literature to date, whereas the Work Ability Index has been widely used as a research tool.

1.3.1. The Work Ability Index

The Work Ability Index was devised by The Finnish Institute of Occupational Health, as a tool to determine how effective workers are, at present, and likely to be in the near future, in order to maintain, or promote, the work ability of employees (Ilmarinen, 2007). The Work Ability Index, which has been translated into 24 languages, assesses workers' subjective perception of the physical and mental demands of work, in conjunction with the workers' health status and personal resources. The questionnaire comprises seven dimensions, two of which, work ability in relation to the demands of the job and mental resources, represent central constructs of the job-demand-control models. Perhaps unsurprisingly therefore, the Work Ability Index has been found to be associated with mental demands (Tuomi *et al.*, 1997b; Tuomi *et al.*, 2001; Sjögren-Rönkä *et al.*, 2002; Tuomi *et al.*, 2004; Bethge & Radoschewski, 2010), physical demands (Tuomi *et al.*, 1991; Ilmarinen *et al.*, 1997; Tuomi *et al.*, 1997a; Pohjonen *et al.*, 2001; Tuomi *et al.*, 2001; Aittomäki *et al.*, 2003; Tuomi *et al.*, 2004), autonomy, (Pohjonen, 2001; Tuomi *et al.*, 2001) support, (Ilmarinen *et al.*, 1997; Borg *et al.*, 2003; Sugimura & Thériault, 2010), job-security (Lindberg *et al.*, 2005) and

inadequate income (Knezevic *et al.*, 2009) Additionally, shift workers display lower levels of Work Ability Index than daytime workers, which may also be indicative of differences in the reciprocity of efforts and rewards (Capanni *et al.*, 2005).

Although mental and physical demands both demonstrate a negative relationship with the Work Ability Index, Tuomi *et al.* (2001) found the work ability of physical workers to be significantly poorer than that of workers performing jobs involving mental demands. Similarly, Aittomäki *et al.* (2003) reported there to be higher incidence of lowered work ability in blue-collar workers compared with white-collar workers of both genders, which was largely explained by differences in physical stress exposure at work. Additionally, having a physically non-strenuous job has been found to be one of the most important factors for employees' retaining their workability (Lindberg *et al.*, 2005). The extent to which this constitutes a genuine difference in the ability of these workers to perform their jobs is unclear, as the Work Ability Index applies a weighting depending upon whether a job is predominantly mental or physical in nature, which reduces the overall score for physical workers. However, this may be justified, as incidence of disease has long been known to differ according to social economic status (Syme & Berkman, 1976) with a significant proportion of the variance in levels of perceived good general health, across socio-economic strata, being attributed to differences in both exposures to hazardous physical stressors, and the degree of control, at work (Schrijvers *et al.* 1998). Three possible mechanisms have been proposed to explain the association between socioeconomic status, work

environment and health: i) socioeconomic status directly influences the work environment which in turn affects health status; ii) socio economic status may exert an influence upon both health and working conditions; iii) Health influences work environment and socioeconomic status, as individuals with poor health status migrate towards poorer jobs and lower socioeconomic status (Borg *et al.*, 2000).

1.3.2. The Health and Safety Executive's Management Standards

In the UK, The Health and Safety Executive, who act as the national independent watchdog for work-related health, safety and illness, currently advocate the use of a risk assessment approach, based on their management standards, to identify environments associated with poor health. Employers have a legal duty of care to their employees (Health and Safety at Work Act, 1974; Management of Health and Safety at Work Regulations, 1999) and the Management Standards approach was developed with the aim of reducing incidence of stress-related illness at work (McKay *et al.*, 2004). Such an approach is based upon the belief that “a preventative, risk-assessment based approach is more effective than case-based methods in achieving a nationwide reduction in work-related stress” (Cousins *et al.*, 2004, p113). The management standards cover six dimensions of the work environment which if not properly managed are associated with poor health and well-being, lower productivity and increased sickness absence: *demands, control, support, relationships, role and change*. The standards therefore draw heavily upon the demand-control-support model. *Demands* include factors such as workload, work patterns and the work environment.

Control relates to the extent to which an employee can choose how to perform their work. *Support* includes both resources and encouragement, and can also be subdivided into peer support and management support. *Relationships* relates to positive working and avoidance of conflict. Factors which contribute towards the dimension of *role* are understanding of role and having non-conflicting roles. Finally *change* relates to management and communication of change within the organisation. For each standard the Health and Safety Executive provide a definition for acceptable practice, i.e. for demand the standard is “employees indicate that they are able to cope with the demands of their jobs; and systems are in place locally to respond to any individual concerns” (Health and Safety Executive, 2009, p.5).

Despite the fact that the Management Standards Indicator Tool is intended for use at the organisational level to identify areas of the psychosocial work environment, Edwards *et al.* (2008) suggest that it may be capable of providing a single measure of strain. Scores on the Management Standards Indicator Tool have been certainly been found to demonstrate associations with other work-related psychosocial factors: Kerr *et al.* (2009) reported positive associations with job satisfaction and negative associations with job-related anxiety (Kerr *et al.*, 2009), whilst Bevan *et al.* (2010) reported that all 7 dimensions of the tool were positively associated with work stress.

1.4. ALTERNATIVE METHODS OF ASSESSING WORK STRAIN

At present, assessment of psychosocial hazard at work is based almost exclusively upon self-rating questionnaires (Maina *et al.*, 2009a), and the appeal of this methodology undoubtedly owes much to its simplicity and ease of application by non-specialist staff. However, the theoretical models underlying these assessment tools appears to represent a conceptual weakness in the ability to adequately account for the ubiquitous range of variables that can influence the work-related well-being of employees. For instance, the fact that support is most effective at moderating job strain when the recipient is unaware of its presence (Bolger & Amarel, 2007) is an example of a variable that a subjective questionnaire cannot possibly account for. Indeed, the limitations of this one dimensional, subjective, methodology are becoming increasingly recognised, with Sjögren-Rönka *et al.* (2002) arguing that assessment of work ability should incorporate both objective and subjective evaluations of employees' resources in relation to work, and life demands. Eller *et al.* (2006) advocate the use of including physiological assessment in studies of occupational stress to improve existing models. Similarly, Hanson *et al.* (2001) and Johnston *et al.* (2013) both point to the necessity of adding ambulatory assessments of work-related well-being to traditional approaches, in order to understand the psychobiological responses to the work environment. Perhaps, therefore, rather than continuing the trend towards the development of increasingly complex models and subjective assessment tools, adopting an ambulatory assessment of work-related well-being may provide a more accurate appraisal of how effectively employees are coping with the demands of their jobs.

1.4.1. Ambulatory Assessment

According to Fahrenberg (1996), “Ambulatory assessment involves the acquisition of psychological data and/or physiological measures in everyday life (i.e. natural settings)” (p.2). Behavioural and Health psychology have embraced a variety of methods for collecting real time data in the field (Shiffman & Stone, 1998). ‘Ecological momentary assessment’ or the ‘experience sampling method’ involves repeated sampling of an individual’s experiences and behaviour, in their natural environment (Shiffman *et al.*, 2008). Ecological momentary assessment designs enable investigation of dynamic processes (Smyth & Stone, 2003) and offer a reliable method for assessing events, subjective experience and physiological variables in the setting of interest (Stone & Shiffman, 1994). The literature relating to the use of both psychosocial and physiological processes will be addressed in turn in the following sections.

1.4.2. Ambulatory Psychosocial Assessment

In psychological research, respondents often make retrospective ratings of their emotional experiences after an extended period of time. In the work domain this generally requires an individual to attempt to recall, average, and summarise their daily work-related experiences (Kamarck *et al.*, 2007). However, self-report of experience relying upon the process of retrospective recall is subject to numerous sources of bias (Smyth & Stone, 2003) as a result of our inability to fully encode details of past experience in memory or to completely decode the details at the time of recall (Bradburn *et al.*, 1987). People not only ascribe greater importance to recent events in comparison to more distal ones (Levine & Safer, 2002), but

also place undue emphasis upon the magnitude of the most intense experience of a specific episode at the cost of duration, or frequency with which events occur (Stone *et al.*, 2005). This phenomenon is known as the peak and end rule (Fredrickson & Kahneman, 1993). Furthermore, recall has also been shown to be influenced by the state that exists at the time of recall. Nonetheless, despite the potential confounding effects of recall bias, this is still a valuable research methodology as it places relatively little additional demand upon the participants during data collection, albeit at the expense of accuracy.

The alternative methodology is to attempt to capture momentary data. Momentary self-reports involve the individual making an assessment of their thoughts, feelings or behaviour at a specific moment in time, therefore eliminating any potential bias from recall or summation. These representative samples can then be transformed into average, or cumulative values. Although Csikszentmihalyi (1977) is generally credited as being the first to implement the technique in its current form, Scollon *et al.* (2003) point to use of similar techniques from as early as the 1920's. However, organisational and occupational health research has been rather slow to adopt the technique. The experience sampling method is typically used to investigate the extent to which dynamic changes in one state measure are associated with changes in another state variable, normally focusing on how naturally occurring events and experiences, within field settings, influence individual's feelings, attitudes and behaviours (Dimotakis *et al.*, 2013). For assessment of psychological processes the experience sampling method can be performed using one of three sampling

methods: signal based, interval based or event contingent. Signal based experience sampling is perhaps the most commonly used approach and requires the participant to be alerted to the fact that they must provide a sample by means of some sort of random, or semi random signal. Interval contingent sampling involves sample, at predetermined intervals, which relates to the preceding period, or the period between signals. Although, these studies generally reduce the time period over which an individual is required to recall some information, compared with traditional recall methods they cannot entirely eliminate the bias inherent in this process. Event contingent sampling requires the participants to initiate a sample at the occurrence of an event which the study wishes to address. Of additional interest, where psychophysiological mechanisms are being investigated, is the fact that biologic processes involved in the stress response may be more closely connected to the experiencing self than the remembering, or believing selves. In acknowledgement of the differential processes involved with each of the three conscious selves, Conner and Barrett (2012) recommend that ambulatory self-reports are used when connecting psychological with stress-related biologic processes. Certainly, the results from the Pittsburgh Healthy Heart study (Kamarck *et al.*, 2005, Kamarck *et al.*, 2007) suggest that psychosocial experience during daily life may alter hemodynamic activity. Individuals reporting their lives as more demanding by daily diary report tended to show greater carotid intima-media thickness. Furthermore, whilst ecological momentary assessment measures of task demand were associated with carotid intima-media thickness, scores of trait demand from Karasek's job-demand control model were not. Kamarck *et al.* (2005) also identify that future work should consider the relationship between ecological momentary assessment and more

specific markers of sympathetic and parasympathetic activation. In their recent review of the literature, Conner and Barrett (2012) show that ambulatory reports of daily experience demonstrate greater associations with autonomic processes than either retrospective or trait measures. Similarly, affect measured using ambulatory self-report has been shown to demonstrate greater associations with cortisol than when measured using trait questionnaires (Steptoe *et al.*, 2007). The experience sampling method is particularly valuable within idiographic research, as it allows for consideration of processes occurring at the within-individual level (Scollon *et al.*, 2003).

1.4.3. Ambulatory Blood Pressure

It has long been recognised that the environment within which stress-related physiology is measured is an important consideration. The phenomenon of white coat hypertension whereby an individual finds the experience of clinical blood pressure monitoring inherently stressful, resulting in a temporarily elevated blood pressure (Verdecchia *et al.*, 1994), illustrates the practical implications of assessing the physiological stress response. This issue can be resolved through the use of ambulatory devices, which have been used since the first half of the 20th century (Kubiak & Stone, 2012). Ambulatory blood pressure monitoring provides a better predictor of risk of cardiovascular events than office based measurement (Verdecchia *et al.* 1994; Ohkubo *et al.*, 2005; Pickering *et al.*, 2005). Ambulatory monitoring can also detect the presence of masked hypertension, where clinical blood pressure is normal but ambulatory blood pressure is elevated. Masked hypertension is associated with increased cardiovascular risk

and has been observed in 10-30% of adults (Lansbergis *et al.*, 2008). Although ambulatory blood pressure monitoring does not entirely eliminate potential sources of error, with arm placement in particular having the potential to influence readings (Beevers *et al.*, 2001; Mourad *et al.*, 2003), the ecological validity afforded by the technique is invaluable. Indeed, ambulatory blood pressure monitoring is now a mandatory requirement within clinical pharmacological research (O'Brien *et al.*, 2003) and normative values have been established (O'Brien *et al.*, 2003; Pickering *et al.*, 2005). As acute stress exposure can increase blood pressure by more than 30 mmHg (O'Brien *et al.*, 2003), the assessment of blood pressure should have the capacity to identify the presence of work-related psychosocial stress.

1.4.4. Heart Rate Variability

Heart rate variability refers to the oscillation in the time period between consecutive heartbeats, usually measured as the time between sequential R waves; the largest peaks in the electrocardiogram trace of heart activity (Pumprla *et al.*, 2002). Variability in heart rate is a normal phenomenon, resulting primarily from the dual innervations of the sinus node by both the sympathetic and parasympathetic components of the autonomic nervous system (Pumprla *et al.*, 2002). A high variability in heart rate demonstrates effective adaptation and functioning of the autonomic nervous system and, conversely, low heart rate variability is often indicative of abnormal autonomic functioning. Accordingly, analysis of heart rate variability provides a useful, non-invasive, method of assessing the functionality of the autonomic nervous system (Task Force of the

European Society of Cardiology and The North American Society of Pacing and Electrophysiology., 1996; Pumprla *et al.*, 2002; Malliani, 2005). Despite being subjected to extensive investigation the physiology underlying heart rate variability remains unknown (Billman, 2011).

Heart rate variability can be analysed and expressed in numerous ways, the most simplistic of which are time domain measures, which provide simple measures of the mean intervals between consecutive normal heart beats (mean normal to normal, or NN interval), or the difference between the shortest and longest NN interval (Task Force of the European Society of Cardiology and The North American Society of Pacing and Electrophysiology., 1996). A number of further time domain variables can be derived from statistical and geometric analysis of the NN interval including the standard deviation of the NN interval (SDNN), and the standard deviation of the average NN interval (SDANN). Whilst time domain variables are sensitive to abnormalities in autonomic functioning, they can only provide a non-specific assessment of sympathovagal balance, as they contain no information relating to the relative influence of each branch of the autonomic nervous system (Pumprla *et al.*, 2002).

Spectral analysis of heart rate variability allows for quantification of the variability of the signal occurring within distinct frequency components, normally through use of either the fast Fourier transform, or autoregressive methods (Task Force of the European Society of Cardiology and The North American Society of Pacing and Electrophysiology., 1996). The spectral profile of human heart rate variability

consists of four main components: low frequency (0.025 to 0.15 Hz), high frequency (0.15 to 0.4 Hz), very-low frequency (0.003-0.05Hz) and ultra-low frequency (0.0001 to 0.003 Hz), although low frequency and high frequency are most commonly used, and ultra-low frequency can only be determined from long term recordings (Task Force of the European Society of Cardiology and The North American Society of Pacing and Electrophysiology., 1996). High frequency fluctuations correspond to respiration rate and are widely regarded as being a satisfactory marker of parasympathetic activity (Karemaker, 2001; Malliani *et al.*, 2005; Montano *et al.*, 2009). The exact mechanisms underlying variations in the low frequency component of heart rate variability are less well understood. The low frequency component was once assumed to be under sympathetic control (Karemaker, 2001); however several studies have revealed that low frequency power does not represent sympathetic modulation alone (Hopf *et al.*, 1995; Houle & Billman, 1999). Indeed, it appears that the low frequency power represents both branches of the autonomic nervous system, and is largely mediated by parasympathetic influences, with any contribution from the sympathetic system occurring as an indirect result of baroreflex function (Malliani *et al.*, 1994; Grasso *et al.*, 1997; Karemaker *et al.*, 2001; Moak *et al.*, 2009).

The lack of clarity surrounding the magnitude of, or the precise mechanisms behind, the influence of the sympathetic nervous system upon low frequency power, may be attributable to the ambiguity of results from spectral analysis (Maimy, 2006). The lack of both a gold standard for the assessment of the autonomic nervous system from spectral analysis of heart rate variability

(Goldberger, 1999), and a standardised method for the pre-processing of the heart rate variability signal (Kuss *et al.*, 2008) has resulted in widely disparate frequency ranges being attributed to each component of heart rate variability (Sandercock, 2007) which certainly complicates the interpretation of results. However, whilst low frequency power may not directly represent activity of the sympathetic nervous system, spectral analysis of heart rate variability can, nonetheless, provide a more accurate indication of the direction, and magnitude, of variations in sympathovagal balance (Pumpela *et al.*, 2002; Acharya *et al.*, 2006; Malliani, 2005; Montano *et al.*, 2009) with a high frequency leaning indicating parasympathetic dominance and enhanced low frequency power revealing predominantly sympathetic control. Accordingly, spectral analysis is preferable to time domain analysis when the balance of the autonomic nervous system is important, as is the case for studies of work related strain, given the association between stress and sympathetic activation.

Common indices of heart rate variability obtained from spectral analysis are the total power of the signal, the power of the individual frequency components, and the ratio of the high frequency and low frequency components (low-to-high frequency ratio). The power of the high frequency and low frequency components can be expressed in absolute terms or as normalized units, where the relative value of each component is calculated in proportion to the total power minus the very low frequency (Montano *et al.*, 2009). Normalisation minimizes the effect of changes in total power upon values of low frequency and high frequency power (Task Force of the European Society of Cardiology and The North American

Society of Pacing and Electrophysiology, 1996) and aids interpretation of data (Malliani *et al.*, 1994; Montano *et al.*, 1994). Two main durations for recording heart rate variability are generally used: short-term recordings, of between two and five minutes, and long-term recordings obtained over a twenty four hour period. Long term recording is the only technique that allows for quantification of the ultra-low frequency, and spectral analysis can be performed from either, the entire twenty four hour recording, or from shorter segments averaged over the same period. There is, however, evidence that spectral analysis of heart rate variability recordings obtained over both one hour and twelve hours can accurately estimate the low frequency and high frequency parameters of heart rate variability over twenty four hours, but not the ultra-low frequency component (Fauchier *et al.*, 1998).

All time and frequency domain indices have been shown to decrease with age , with the exception of the low-to-high frequency ratio which increased with age, although the decrease in low frequency power was more pronounced after age fifty (Antelmi *et al.*, 2004). This is in agreement with the findings of Britton *et al.* (2007), who reported that middle aged men demonstrated significant decreases in both time and frequency dimensions, over a five year period, with the biggest decrease occurring in low frequency power. Kuo *et al.* (1999) found that absolute measurements of heart rate variability follow a linear decrease between age forty and eighty with no change being evident in normalised units until after age 60. Additionally, Zhang (2007) found that whilst total power of heart rate variability decreased with ageing, the period between twenty years and fifty years

demonstrated the smallest variance in power ranges, with marked decreases occurring between ten and twenty, and another between fifty and eighty years. It is believed that the decrease in heart rate variability with age is a consequence of older people becoming more sedentary (Zhang, 2007).

The commercial availability of minimally invasive ambulatory electrocardiogram monitors has led to the increasingly widespread use of ambulatory heart rate variability as a research tool (Task Force of The European Society of Cardiology and The North American Society of Pacing and Electrophysiology, 1996). As with all field-based assessments, ambulatory electrocardiogram monitoring provides enhanced ecological validity compared to laboratory investigation, albeit at the expense of a decrease in experimental control. Whether this constitutes a concern or not depends predominantly upon the experimental design specifically whether heart rate variability represents an independent or dependent variable. However, with the exception of research concerned with the health outcomes of heart rate variability, researchers are primarily interested in the environmental or behavioural determinants of heart rate variability.

1.4.5. Assessment of hypothalamic-pituitary-adrenal function: salivary free cortisol.

Although assessment of the hypothalamic-pituitary-adrenal axis at different levels in humans is not without its practical and conceptual challenges, the axis is one of the most widely investigated physiological systems in health psychology

(Nicolson, 2008). Cortisol, as the end point of the hypothalamic-pituitary-adrenal axis is the most commonly used measure of the axis within humans and is widely considered to be a reliable biomarker of activity within the hypothalamic-pituitary-adrenal system (Preussner *et al.*, 1997). As unbound cortisol enters cells via a process of passive diffusion it is possible to measure cortisol in all bodily fluids (Kirschbaum, 2010). Furthermore, as the acinar cells of the saliva glands prevent protein bound molecule from entering saliva, cortisol measured in saliva represents a measure of free cortisol (Kirschbaum & Hellhammer, 1994). This is useful as the free hormone hypothesis (Mendel, 1989) states that “the biological activity of a given hormone is affected by its unbound (free) rather than protein-bound concentration” (p. 232). Saliva is therefore the preferred fluid from which to assess cortisol (Soo-Quee & Choon-Huat, 2007). A further benefit of sampling cortisol via saliva is that it allows for relatively stress-free sampling (Kirschbaum & Hellhammer, 1994; Gröschl, 2008; Hellhammer *et al.*, 2009) that can be accurately performed out with a laboratory setting (Kirschbaum & Hellhammer, 1999; Levine *et al.*, 2007; Wilhelm *et al.*, 2007). That the method of sampling does not itself elicit a stress reaction is a significant consideration for stress research, as is enhancing ecological validity through sampling in the naturally occurring environment (Fahrenberg *et al.*, 1996). Cortisol sampling can provide two main measurements: daytime cortisol profile and cortisol awakening response. Assessment of the day time cortisol profile requires the collection of numerous blood or saliva samples, over a long period of time and is relatively expensive and time consuming (Wüst *et al.*, 2000). Furthermore, daily cortisol secretion has been found to be unrelated to work related stress (Pollard *et al.*, 1996; Maina *et al.*, 2009a).

The cortisol awakening response is an alternative index of hypothalamic-pituitary-adrenal activity, characterised by levels of cortisol increasing significantly within the first 30 minutes following awakening, and remaining elevated for at least an hour (Preussner *et al.*, 1997; Wüst *et al.*, 2000). The hypothalamic-pituitary-adrenal axis is known to display a circadian rhythm, which is clearly evident in the pattern of cortisol release, where between 10 and 15 secretory episodes occur over the course of a day, with levels peaking early in the day and steadily diminishing thereafter (Stone *et al.*, 2001). The cortisol awakening response is a distinct element of the diurnal pattern of cortisol release (Clow *et al.*, 2004; Fries *et al.*, 2009; Powell & Schlotz, 2012), which is believed to represent a response to the reactivation of memory upon waking (Wilhelm *et al.*, 2007) and anticipation of the demands to be faced in the day ahead (Fries *et al.*, 2009). The two principal parameters of the cortisol awakening response are total cortisol secretion over the awakening period and the increase in cortisol over the same period (Preussner *et al.*, 2003; Chida & Steptoe, 2009). The increase in cortisol over the awakening period provides information pertaining to the sensitivity of the system and is likely to constitute the most appropriate measure for reactivity of the hypothalamic-pituitary-adrenal axis in relation to psychosocial factors (Chida & Steptoe, 2009).

Although several authors claim that the cortisol awakening response contains high levels of intra-individual stability (Preussner *et al.*, 1997; Wüst *et al.*, 2000a; Wüst *et al.*, 2000b; Lai *et al.*, 2005; Hucklebridge *et al.*, 2005; Wilhelm *et al.*, 2007; Maina *et al.*, 2009; Thorn *et al.*, 2009) there is a reasonable body of

evidence to suggest that the response varies significantly from day to day (Kirschbaum & Hellhammer, 1999; Stone *et al.*, 2001; Hruschka *et al.*, 2005; Adam *et al.*, 2006; Almeida *et al.*, 2009; Dahlgren *et al.*, 2009; Stalder *et al.*, 2009; Stalder *et al.*, 2010; Ross *et al.*, 2014). The cortisol awakening response has been shown to be sensitive to chronic stress exposure, such as that experienced during military training (Clow *et al.*, 2006) and is also sensitive to acute psychosocial factors and can be moderated by coping resources such as humour (Lai *et al.*, 2010). The cortisol awakening response, therefore, represents a useful indication of the levels of psychological strain experienced in daily life. Indeed, a recent review (Chida & Steptoe, 2009) reported that the cortisol awakening response is positively associated with general life stress, and earlier studies have found it to correlate to both chronic (Wüst *et al.*, 2000a) and acute stress (Preussner *et al.*, 2003).

1.5. THE INDIVIDUALITY OF STRESS REACTIVITY

Assessment of physiological functioning during exposure to the psychosocial stressors experienced in the workplace may provide a valuable indication of the degree of strain being experienced, and an insight into the interaction of multiple variables affecting work ability. However, much of the existing research appears to have made the assumption that individuals will demonstrate similar physiological responses to a given degree of strain. A common method of analysis is to categorize individuals according to a subjective assessment of work strain and then seek associations with physiological response and, whilst numerous significant associations have been found to exist, inter-individual

variance in the physiological response is often considerable. Certainly, where the relationship between subjective measures of work strain, or work ability, physiological response and sickness absence is of interest, it would be imprudent not to give consideration to the possibility that individuals may actually respond quite differently to an identical imbalance between demands and resources.

Despite the existence of a clear association between stress exposure and disease, the fact that not everyone exposed to stress develops a stress-related disease is important. The stress reactivity hypothesis posits that the degree of physiological activation occurring in response to a stressor is an individual characteristic, and it is this which determines susceptibility, or resilience, to disease (Cacioppo *et al.*, 1998). Therefore, an identical stimulus may result in significantly different physiological reactivity across individuals, even when they have similar resources available to them. There is a substantial amount of evidence to support the heterogeneity of the response of the autonomic nervous system to acute laboratory stressors, with the reactivity of heart rate, heart rate variability and blood pressure demonstrating significant inter-individual differences. In their review, Treiber *et al.* (2003) reported that there is reasonable evidence to show that cardiovascular reactivity to laboratory stressors can predict pre-clinical disease.

Cardiovascular reactivity to laboratory stressors has been found to be capable of predicting future blood pressure status (Matthews *et al.*, 1993; Flaa *et al.*, 2008) and the development of hypertension and cardiovascular disease, both clinical

and sub-clinical (Menkes *et al.*, 1989; Trieber *et al.*, 2003). Sympathetic nervous reactivity during psychological stress has also been found to predict future blood pressure (Flaa *et al.*, 2008). Whether cardiovascular reactivity can be considered to be of prognostic value is questionable, however. Certainly, Carroll *et al.* (1995) reported that blood pressure reactivity to a laboratory-based stressor provides minimal predictive power over and above that provided by baseline blood pressure, and is therefore not a useful clinical index for the prediction of future blood pressure. There is emerging evidence to suggest that a blunted cardiovascular reactivity to stress is also related to certain poor health outcomes, such as depression and obesity (Phillips, 2010), with a recent review suggesting that stress reactivity which falls below, or exceeds, a normative midrange may be associated with negative health outcomes as a result of a loss of homeostasis (Lovallo, 2010).

The potential for cardiovascular reactivity to predict illness other than hypertension was shown by Boyce *et al.* (1995) who conducted two studies to investigate the relationship between reactivity and respiratory illness rates in a cohort of children. One study considered cardiovascular reactivity to a lab-based stressor, whilst the other investigated immune responses to the natural stressor of beginning school. The results of both studies revealed that children who demonstrated the greatest reactivity were found to have higher incidence of illness in the following 6 month period where their childcare situation was considered to be high in stress and lower illness rates where they were exposed to less stressful childcare, compared to low reactors. Significantly, stress exposure was not associated with greater incidence of illness amongst low

reactors. More recently, Boyce *et al.* (2005) hypothesised that stress reactivity may be determined during childhood, with exposure to both highly stressful and highly protective environments having the ability to influence an individual's reactivity throughout their life. If this finding extrapolates to the effects of work-related strain exposure upon adults, then assessment of the degree of strain present represents a rather blunt tool for assessing pathology. That increased immune reactivity was associated with greater rates of illness appears counterintuitive, and this may reflect a methodological weakness. As the stressor was not under control then variance in immune reactivity may reflect real differences in stress exposure. Certainly, Marsland *et al.* (2002) found that individuals who demonstrated a greater suppression of immune function in response to a laboratory stressor mounted a lower antibody response to a hepatitis B vaccination suggesting that individual immune reactivity may well moderate the relationship between psychological stress and disease. Furthermore, previous studies (Cohen *et al.*, 2000; Cohen *et al.*, 2002) have found that individuals with a low immune response to a laboratory stressor demonstrated higher rates of upper respiratory illness when exposed to high stress compared to low stress, whilst the degree of stress exposure had no influence upon rates of upper respiratory illness amongst high immune reactors. A similar relationship has been found for neuroendocrine reactivity, as individuals who demonstrated a high cortisol response to a lab based stressor, and reported high life stress, experienced a greater incidence of upper respiratory illness than both high reactors with low stress and low reactors irrespective of stress exposure (Cohen *et al.*, 2002).

The extent to which individual differences in reactivity generalize beyond the laboratory and are representative of reactivity to real-life stressors is of crucial importance, if individual reactivity is to hold any predictive power for future ill-health risk, yet findings remain inconclusive. Numerous studies have found that laboratory based and real life cardiovascular reactivity yield poor, or limited, agreement (Van Egeren and Sparrow, 1989; Kožená *et al.*, 1998; Davig *et al.*, 2000; Fauvel *et al.*, 2001). However, Kožená *et al.* (1998) found that systolic blood pressure and diastolic blood pressure responses in a real life emergency situation correlated to those obtained experimentally. Whilst, Pattyn *et al.* (2010) observed differences in cardiovascular reactivity to a lab based mental stressor and to real life exam stress, it is not clear whether this resulted from the difference in the type of stressors or that the exam stress represented a more chronic stress. It certainly remains unknown whether reactivity to acute laboratory stressors bears any correlation to reactivity during exposure to chronic, naturally occurring, stressors (Ho *et al.*, 2010).

Whilst the exact mechanisms responsible for the variance in stress reactivity are unknown, increased activity in the posterior cingulate cortex has been observed amongst individuals who demonstrate a high cardiovascular reactivity to a psychological stressor, suggesting that high reactors either invest a greater degree of attention or vigilance to the stressor, or they evaluate it as having a greater emotional or motivational content (Gianaros *et al.*, 2005; 2007). There are also a number of factors; physical, environmental, and psychological, which moderate an individual's physiological reactivity to stress, such as aerobic

conditioning (Spalding *et al.*, 2004), social support (Kamarck *et al.*, 1990; Uchino & Garvey, 1997; Uchino, 2006; Uchino *et al.*, 2010) and personality traits (Cosley *et al.*, 2010). Highly trained elite sportsmen display significantly lower cortisol and heart rate reactivity to stress than untrained men (Rimmele *et al.*, 2009), although the effect of more moderate levels of cardiovascular training upon reactivity is less clear. One study reported that trained men demonstrated the same reduction in reactivity that elite athletes do (Rimmele *et al.*, 2007), whilst another found that amateur sportsmen display a disassociation between sympathetic and hypothalamic-pituitary-adrenal responses, with heart rate being lower than in untrained men but no difference existing in cortisol response (Rimmele *et al.*, 2009). The presence of social support can reduce cardiovascular reactivity to laboratory stressors, even whilst the degree of perceived stress remains unchanged (Uchino & Garvey, 1997), which has significant implications in terms of the assessment of work-strain by traditional subjective questionnaires. However, the effect of social support upon cardiovascular reactivity is, itself, influenced by individual personality traits such as compassion (Cosley *et al.*, 2010) and forgiveness. In fact, for defensive individuals the presence of social support has been found to increase cardiovascular reactivity to a stressor. Cardiovascular reactivity to stress is also known to be associated with age. Uchino *et al.* (1999) reported that age predicted an increase in systolic blood pressure reactivity during exposure to acute experimentally induced psychosocial stressors (speech and maths tasks), which was attributed to increases in both cardiac output and total peripheral resistance. Older individuals demonstrated greater increases in sympathetic activation and greater vagal withdrawal than younger individuals.

Test-retest reliability of individual reactivity is enhanced by considering reactivity to multiple stressors (Kelsey *et al.*, 2007) but it is unclear whether this remains the case when the stressors differ significantly in nature. Several studies have reported that individuals who demonstrate high reactivity to exercise stress also display high reactivity to psychological stress (Singh *et al.* 1999; Negrão *et al.* 2000), however others have reported there to be little, or no, association between reactivity to physical and psychosocial stress. Additionally, differences in the specific demands of psychological stressors may result in different responses, as psychological tasks requiring effort and attention appear to predominantly activate the sympathetic nervous system whilst tasks which pose a greater threat or cause distress, elicit responses from both the sympathetic nervous system and the hypothalamic-pituitary-adrenal axis (Lundberg & Frankenhaeuser, 1980). Furthermore, it is also important to recognise that even where individuals have been found to be highly reactive to both exercise and psychological stress, the magnitude of the response differs considerably. The increase in adrenocorticotropin occurring in response to a laboratory based exercise stress is five times that, which occurs for laboratory psychological stress, and increases in cortisol are twice as large (Negrão *et al.*, 2000). Given that physiological adaptations, which occur in response to the demands of exercise, are likely to cause an overestimation of reactivity to physical strain, it has been suggested that the anticipatory response to exercise may correlate better to individual reactivity to psychological stress (Kamarck & Lovallo, 2003). The distinction between physical and psychological stressors is not the only determinant of physiological response, as psychological tasks requiring effort and attention appear to predominantly activate the sympathetic nervous system, whilst tasks

which pose a greater threat or cause distress, elicit responses from both the sympathetic nervous system and the hypothalamic-pituitary adrenal axis (Lundberg & Frankenhaeuser, 1980).

Notwithstanding the ability of laboratory based reactivity to predict future health states, if the reactivity hypothesis is correct in its fundamental premise that the magnitude of an individual's reactivity to stress moderates their disease risk, then it would appear intuitive that ambulatory assessment of reactivity during work; a significant source of stress, should provide a more accurate prediction of future health and therefore work ability. Indeed, in their review of cardiovascular responses to stress and the development of cardiovascular disease Schwartz *et al.* (2003) suggested that research would benefit from the assessment of reactivity in the natural environment. Additionally, the finding that stress exposure can predict illness risk, even in the absence of perceived differences in stress (Cohen *et al.*, 1993), suggests that ambulatory monitoring of stress reactivity during working hours may offer greater accuracy in the prediction of absence rates than can be obtained from subjective questionnaires

CHAPTER 2. Literature Review

2.1 INTRODUCTION

This section provides a critical review of the current literature relating to the assessment of psychosocial work strain. Section 2.1 investigates the use of the job-demand-control models and the effort-reward-imbalance model for assessing work strain, both conceptually and in terms of associations with physiological measures. Section 2.2 focuses upon the literature relating to the application of the Work Ability Index and the Health and Safety Management Standards Indicator Tool. Section 2.3 addresses the literature reporting upon the use of ambulatory blood pressure monitoring within the workplace. Section 2.4 attends to the ambulatory assessment of heart rate variability as a measure of reactivity to the working environment while section 2.5 does the same for the cortisol awakening response. Section 2.6 investigates methodological considerations for the sampling of the cortisol awakening response, Section 2.7 investigates the extent to which the current literature gives consideration to the dynamic nature of the work environment and intra-individual variation in psychophysiological reactivity to the acute work environment. Section 2.8 provides a summary and highlights the gaps in the existing literature while section 2.9 details the aims and objectives of the thesis.

2.2. DEMAND-CONTROL & EFFORT-REWARD MODELS

There is considerable support within the literature for the strain hypothesis of the job-demand-control model, with high strain jobs being associated with greater levels of job dissatisfaction and higher levels of perceived stress (De Jonge *et al.*,

2000a; De Bruin & Taylor, 2006). High-strain jobs are also conducive to poor health outcomes, such as exhaustion and poorer psychosomatic and physical health (De Jonge *et al.*, 1999; De Jonge *et al.*, 2000; De Jonge *et al.*, 2000a), whilst the association between high-strain jobs and risk of cardiovascular disease has been known for almost 30 years now (Karasek *et al.*, 1981). Although a recent meta-analysis (Duijts *et al.*, 2007) identified that control at work is an important predictor of future sick leave, the extent to which control buffers the effect of work demands is unclear (De Jonge & Kompier, 1997). A recent analysis of demand-control related studies (Taris, 2006) reporting that only 10% of the research offered support for the interaction effect of demands and control. Certainly, for women in active jobs, where both demands and control are high, the hazard for negative health outcomes is the same as in high strain jobs (Krantz & Ostergren, 2002). It appears that, for active jobs at least, modern working conditions often vary according to gender, and subjective assessment by the job-demand-control model differs from objectively assessed demands and control in opposite directions for men and women, with women underestimating the extent of adverse conditions (Waldenström & Härenstam, 2008). However, Shultz *et al.* (2010) reported that, although only a single association existed between possible job-control mechanisms and job demands in a cohort of younger workers, for older workers all job-control mechanisms buffered the effects of different types of job demand. It is, therefore, possible that as a result of reduced physical and cognitive resources, older workers have a greater need for control, to prevent job demands from causing stress. The results of an earlier study (Santavirta *et al.*, 2005) certainly suggest that a combination of high demands and low control is particularly harmful for older workers.

In common with the original demand control model there is also substantial evidence to support the iso-strain hypothesis of the demand-control-support model (Theorell *et al.*, 1998; Dollard *et al.*, 2000; Pelfrene *et al.*, 2002; Moreau *et al.*, 2004), but findings regarding the buffer hypothesis are less consistent. Whilst Proost *et al.* (2004) found that supervisor support buffers the negative effect of high job demands amongst a cohort of nurses others have reported a lack of a buffering effect for social support (Pelfrene *et al.*, 2002). Furthermore, the extent to which support can moderate the effects of stress appears to be dependent upon the nature of the stressor itself and also upon personality traits. Taylor *et al.* (2010) reported that the presence of social support can actually exacerbate the biological stress response in an evaluative situation and, for individuals with high psychological resources, the presence of social support may undermine self-esteem, causing distress (Bolger & Amarel, 2007). Indeed, social support, which is provided unbeknownst to the recipient, therefore avoiding undermining efficacy, is more beneficial than visible support (Bolger & Amarel, 2007).

As expected, given the original aim of the effort reward imbalance model, a high effort-reward imbalance has repeatedly been found to demonstrate an association with coronary heart disease (Kuper *et al.*, 2002; Bosma *et al.*, 1998) and associated risk factors such as hypertension and high cholesterol (Peter *et al.*, 1998). However, the effort reward imbalance model has also been associated with poor physical and mental functioning (Kuper *et al.*, 2002), as well as with burnout (Bakker *et al.*, 2000). In a recent comparison of epidemiological studies from five European countries, Siegrist *et al.* (2004) found that individuals who

experience an imbalance between effort and reward, or are characterised by over-commitment, have a significantly elevated risk of poor general health. A further review, of 45 studies investigating the effort reward imbalance model (Van Veghel *et al.*, 2005), also found there to be considerable evidence to support the contention that high effort reward imbalance is associated with poor health. However, inconsistent findings regarding the effects of over-commitment were reported, whilst there was found to be a paucity of research relating to over-commitment moderating the relationship between effort reward imbalance and health.

Despite giving consideration to less tangible variables, such as job-insecurity, which has repeatedly been found to demonstrate an association with health status (Barling & Kelloway, 1996; Ferrie *et al.*, 2002; László *et al.*, 2010), the effort-reward-imbalance model arguably still suffers the same weakness as all work strain models. As descriptive models they cannot be expected to fully account for the relationship between work strain and health, without being translated into explanatory models with testable hypotheses. Although, there is some evidence to suggest that the effort-reward-imbalance model provides a better prediction of ill health than the job-demand-control model (De Jonge *et al.*, 2000a) amalgamating the two models may provide a more accurate prediction of ill health than either model alone (Calnan *et al.*, 2000; Ostry *et al.* (2003; Rydstedt *et al.*, 2007; Maina *et al.* (2009b). However, given work strain is only one of numerous causes of ill health these models cannot be expected to account for all of the variance in health status between individuals.

2.3 THE WORK ABILITY INDEX & THE MANAGEMENT STANDARDS

The Work Ability Index is strongly associated with both physical and mental health (Eskelinen *et al.*, 1991; Pohjonen *et al.*, 2001; Kiss *et al.*, 2002; Van den Berg *et al.*, 2008), and also contains a good predictive power for future long-term absence and work related disability (Tuomi *et al.*, 1997b; Kujala *et al.*, 2006; Alavinia *et al.*, 2008; Ahlstrom, 2010). Indeed, Tuomi *et al.* (1997) found that amongst a cohort of workers with poor Work Ability Index, 62.2% had retired on disability pension twelve years later and only 2.4% continued to work full time. However, this is not surprising, as past levels of absenteeism are known to predict future absenteeism (Cohen & Golan, 2007), whilst the presence of at least one long-term illness has been found to be a strong predictor of sickness absence (Andrea *et al.*, 2003). Although Alavinia *et al.* (2008) found that the number of diseases diagnosed by a physician actually had the lowest power for predicting absence; this finding may simply reflect the “healthy worker effect”, where individuals with several diagnosed diseases are likely to have already left the workforce. Furthermore, Gamperiene *et al.* (2008) reported that reductions in health status, both physical and mental, have the most significant effect upon Work Ability Index. However, although important to recognise the association between disease and work ability, the subjective nature of the Work Ability Index can result in inconsistencies in the number of diseases reported, as evidenced by the fact greater disease reporting occurs in the presence of medical professionals (Geissler *et al.*, 2005). Perhaps more importantly, in terms of the potential for preventing poor future Work Ability Index and absence, is the fact that the Work Ability Index provides no information regarding the likelihood of healthy workers

developing disease, and may also contain a ceiling effect for healthy workers (Torgen, 2005). The Work Ability Index may, therefore, be limited in its sensitivity to variance in workability amongst employees with relatively high workability; reducing the opportunity to implement early interventions. There is also evidence to suggest that the promotion of excellent work ability is more dependent upon physical factors whereas preventing poor workability is more heavily influenced by job security and psychosocial factors (Lindberg *et al.* 2006).

It has been shown that employees engaged in mentally demanding work have a greater interest in leisure time physical activity than those employed in physically demanding jobs (Tuomi *et al.*, 1997a), which has implications for the health status of employees. Additionally, Kaleta *et al.* (2006) found a strong association between Work Ability Index and lifestyle factors in both men and women, with leisure time physical activity being heavily implicated in this relationship. The influence that higher levels of leisure time physical activity exert upon reducing perceived stress (Hansen *et al.*, 2010) preventing poor, and promoting good workability has been amply demonstrated (Tuomi *et al.*, 1997a; Tuomi *et al.*, 2001; Tuomi *et al.*, 2004). Furthermore, being overweight is associated with a reduced Work Ability Index (Tuomi *et al.*, 1991; Tuomi *et al.*, 2001; Van den Berg *et al.*, 2008), as is the presence of illness or disease (Kiss *et al.*, 2002; Costa *et al.*, 2005). As scoring of the Work Ability Index is heavily reliant upon measures current health status, it is possible that lifestyle differences between physical and mental workers accounts for much of the variation in workability scores according to the nature of the job.

The Work Ability Index has been shown to decrease with age (Tuomi *et al.*, 1991; Tuomi *et al.*, 1997b; Pohjonen *et al.*, 2001; Kloimüller *et al.*, 2000; Kiss *et al.*, 2002; Sjögren-Rönkä *et al.*, 2002; Capanni *et al.*, 2005; Costa *et al.*, 2005; Goedhard & Goedhard, 2005; Lindberg *et al.*, 2005; Torgen, 2005; Camerino *et al.*, 2006; Monteiro *et al.*, 2006; Chiu *et al.*, 2007; Van den Berg *et al.*, 2008; Knezevic *et al.*, 2009; Bethge & Radoschewski, 2010) with greater age related decrements occurring amongst shift workers than day workers (Costa *et al.*, 2005). Kujala *et al.* (2005) found that the Work Ability Index for the lowest 15th percentile of young workers was 10 points higher than for older workers but (Goedhard & Goedhard, 2005), claim the effect of ageing is relatively small, accounting for less than 10% of the decline in scores over the entire working life with the combined effect of multiple psychosocial factors in the workplace explaining 1.5 times more individual variance than the effect of ageing 40 years (Van den Berg *et al.*, 2008). Therefore, it appears that reduced Work Ability Index with ageing is largely influenced by the incidence of ill-health which increases significantly after age 40 (Pohjonen *et al.*, 2001). Furthermore, of the seven dimensions contained within the Work Ability Index, Chiu *et al.* (2007) found that those pertaining to health and disease demonstrated the most consistent decrement with advancing age. This raises a conceptual issue relating to the direction of the relationship between work ability and ill health. It is certainly possible that prevalence of ill health may exert a stronger influence upon the Work Ability Index than work ability does upon ill health. There are no consistent effects of gender upon workability as some studies have found women to have a lower Work Ability Index than men (Costa *et al.*, 2005; Torgen, 2005; Van den Berg *et al.*, 2008; Bethge & Radoschewski, 2010) whilst others have found no

gender differences to exist (Tuomi *et al.*, 2001; Tuomi *et al.*, 2004; Lindberg *et al.*, 2005).

The Management Standards Indicator Tool is not overly prevalent within occupational health research at present with a recent systematic review of the literature revealing that the tool has only been used within 13 published studies (Brookes *et al.*, 2013). However, these studies have generally involved considerable numbers of participants; a total of 114,794 respondents completed the questionnaire across these 13 studies. With the exception of investigations which have been conducted across multiple cohorts of employees, the largest single group of respondents were 14,270 higher and further education employees (Kinman and Court, 2009). Other groups that have been investigated include health professionals (Hackett *et al.*, 2009; Kerr *et al.*, 2009; Gibb *et al.*, 2010; Verrier & Harvey, 2010), police officers (Houdmont *et al.*, 2012), prison officers (Bevan *et al.*, 2010) and bank workers (Guidi *et al.*, 2012). Brookes *et al.* (2013) highlight the lack of research addressing the impact of exposure to psychosocial hazard, as measured using the indicator tool, as well as there being no attempt to design interventions around the Tool. To date there have certainly been no psychophysiological investigations using the management standards approach within any occupational groups. This may reflect a reluctance to perform investigations where results cannot easily be interpreted in the context of existing findings. Nevertheless this constitutes a significant gap within the current literature, particularly given the emphasis placed upon the management standards by the Health and Safety Executive.

2.4 AMBULATORY BLOOD PRESSURE AND WORK-RELATED STRAIN

There is a compelling body of evidence which demonstrates the existence of an association between work-related strain and ambulatory blood pressure (Theorell *et al.*, 1988; Light *et al.*, 1992; Schnall *et al.*, 1992; Van Egeren *et al.*, 1992; Schnall *et al.*, 1998; Goldstein *et al.* 1999; O'Connor *et al.*, 2000; Vrijkotte *et al.*, 2000; Fauvel *et al.*, 2001; Cesana *et al.*, 2003; Landsbergis *et al.*, 2003; 2003a; Riese *et al.*, 2004; Steptoe *et al.*, 2004; Brown *et al.*, 2006; Guimont *et al.*, 2006). Elevations in ambulatory diastolic blood pressure of around 4mmHg have been reported in workers experiencing high compared to low job strain (Van Egeren, 1992; Fauvel *et al.*, 2001) whilst ambulatory systolic blood pressure has been found to show increases of between 5 and 12mmHg (Schnall *et al.*, 1992; Van Egeren, 1992; Landsbergis *et al.*, 2003). Significantly, it has been reported that ambulatory blood pressure only demonstrates an association with job strain during working hours (Van Egeren, 1992; Fauvel *et al.*, 2001) supporting the use of ambulatory blood pressure monitoring within the environment that is of interest.

Males reporting an effort-reward imbalance have also been found to have an ambulatory systolic blood pressure between 3.9mmHg and 6mmHg higher than men without an imbalance (Vrijkotte *et al.*, 2000; Steptoe *et al.*, 2004) but the importance of over commitment is less clear. Vrijkotte *et al.* (2000) found that neither over commitment, nor the interaction between over commitment and effort-reward imbalance, were associated with ambulatory blood pressure. However, Steptoe *et al.* (2004) reported that over commitment was associated with systolic ambulatory blood pressure, in men but not women.

In general terms ambulatory blood pressure is associated with job strain and effort reward imbalance for males but not for females, although there is evidence that for females ambulatory blood pressure is associated with the demands dimension of the demand control model. Certainly, Cesana *et al.* (2003) found that, whilst systolic blood pressure was elevated amongst men experiencing high, compared to low, job strain there was no association between job strain and blood pressure for women. An earlier study (Light *et al.* 1992), observed differences in both ambulatory systolic and diastolic blood pressure, between high and low strain male workers, although again there was no association present for women. This is not to say the experience of work does not elicit increases in blood pressure amongst women, as ambulatory blood pressure still demonstrates an acute work-related elevation, however the magnitude of this elevation appears to be unaffected by the level of strain present, as determined by the demand control model. Goldstein *et al.* (1999) confirmed that ambulatory blood pressure in women is affected by the experience of work, as amongst a population of female nurses blood pressure was elevated on workdays compared with days off, with diastolic blood pressure being highest during working hours, but no association existed between job strain and ambulatory blood pressure. A more recent study of female nurses (Riese *et al.*, 2004) reported a similar lack of association between job strain and blood pressure during a working day. However the single dimension of job demand was associated with both elevated diastolic blood pressure and systolic blood pressure at work, although in the case of diastolic blood pressure this was only evident when decisional latitude was also high which contradicts the supposed buffering effect of control upon work demands. Whilst Theorell *et al.* (1988) found that overall increases in job strain did result in

elevated systolic ambulatory blood pressure during the working day; changes to job demand exerted a greater effect upon systolic ambulatory blood pressure than changes to autonomy. Furthermore, a recent study of nurses and teachers found that, despite there being no differences in the demand dimension across the two occupational groups, nurses demonstrated significantly higher ambulatory blood pressure at work (Brown *et al.*, 2006). Although the nurses reported lower levels of decisional latitude than the teachers, the difference in stress response may be related to the nature of the demands; nurses deal with critical health situations on a daily basis, which is obviously not the case for teachers. However, as blood pressure is largely influenced by a variety of individual factors, it is difficult to draw inferences from cross-sectional investigations.

The effects of job strain upon blood pressure appear to be cumulative, with Guimont *et al.* (2006) reporting that cumulative exposure to job strain, amongst white collar men, resulted in elevations of blood pressure which were of a magnitude comparable to those associated with sedentary behaviour and age. Schnall *et al.* (1998) found that men experiencing job strain both at baseline and 3 years later had significantly higher ambulatory blood pressure than employees who only reported high levels of job strain at one time point. Additionally, they found that participants who were exposed to job strain upon initial screening, but not at follow up three years later, demonstrated changes in ambulatory blood pressure, which were the opposite of those associated with gaining over forty pounds or ageing fifteen years. The potential to reverse the effects that job-strain

has upon blood pressure, reinforces the importance of having the means to accurately identify individuals who are experiencing work-related strain. Further support for the cumulative effect of work strain on blood pressure was provided by Landsbergis *et al.* (2003a) who revealed that, amongst men with at least twenty five years previous employment, those who had experienced job strain for at least 50% of that time had a working ambulatory blood pressure 4.8mmHg higher than those with no prior job strain. Furthermore, men who experienced job strain for at least 50% of their 25+ year working life and were currently experiencing job strain had a systolic ambulatory blood pressure at work which was 10.0mmHg higher than men who had no previous, or present, exposure to job strain. Although Guimont *et al.* (2006) found that white-collar women demonstrate a similar pattern of blood pressure increase to white-collar men, during exposure to work strain the effect size was substantially smaller. The effect sizes were greater for both men and women reporting low levels of social support at work, which is in accordance with the hypothesis of the job-demand-control support model. The relationship between support at work and blood pressure has been reported previously, in terms of supervisor favourableness, with employees working under an unfavourable supervisor showing significantly higher systolic and diastolic blood pressure than when working under a favourably perceived supervisor (Wager *et al.*, 2003).

The association between work-strain and ambulatory blood pressure appears to be moderated by socioeconomic status, as Landsbergis *et al.* (2003) found the association between job strain and blood pressure to be significantly greater amongst men with a low socioeconomic status compared to those with a high

socioeconomic status, whether determined by occupational status or by educational level. Men with blue-collar jobs and job strain had a mean systolic blood pressure 8.4mmHg higher than that of men with white-collar jobs and job strain. Additionally, men with only a high school education experiencing job strain had a systolic blood pressure 3.8 mmHg higher than college graduates with job strain. Whilst the study found that the differences between socioeconomic groups were not associated with body mass index, smoking, or job related physical exertion, the potential influence of shift work could not be eliminated, as evening and nightshift workers had lower socioeconomic status than dayshift workers. Additionally, O'Connor *et al.* (2000) reported that, within a population of British GPs; who would be considered high socioeconomic status under any criteria, those reporting high levels of strain did have elevated levels of both systolic and diastolic blood pressure, but they did not differ significantly from low strain GPs. This could be argued to offer partial support for the contention that the effect of job strain is buffered within high socioeconomic status employees.

In addition to representing a measure of the degree of psychosocial strain exposure, as a result of its involvement in the development and progression of hypertension, blood pressure may also have the ability to identify individuals at risk of developing work-related hypertension. In England, more than 40% of men and 35% of women over the age of 20 suffer from hypertension (Wolf-Maier *et al.*, 2003) and whilst the incidence of hypertension increases with advancing age, it is still highly prevalent amongst people of working age, affecting 27% of Europeans aged between 35 and 44 years, and 44.2% aged between 35 and 64

(Kearney *et al.*, 2005). Therefore, having the ability to assess the effect that work has upon blood pressure may enable early identification of individuals who are at risk of lowered workability in the future due to disease, and allow for timely implementation of interventions.

2.5 ASSESSMENT OF PSYCHOSOCIAL STRAIN VIA HEART RATE VARIABILITY

Investigations into the effects of psychosocial stress upon time domains of heart rate variability have reported conflicting results. Some studies have found there to be no association between time domain measures of heart rate variability, and both, self-assessed work stress (Langelotz *et al.*, 2008) and job strain quantified by the job-demand-control model (Collins *et al.*, 2005). However, contradictory findings exist, with both work strain (Chandola *et al.*, 2008) and effort reward imbalance (Vrijkotte *et al.*, 2000), having also been found to be inversely associated with time domain measures of heart rate variability. Collins *et al.* (2005) found that low control caused an increase in heart rate variability, whilst high demand reduced heart rate variability, suggesting that the autonomic nervous system may be differentially affected by the two individual components of the job-demand-control model. Spectral analysis of heart rate variability provides slightly more consistent results, with the majority of studies reporting that psychosocial stress is associated with an increase in the low-to-high frequency ratio, reflecting a shift towards sympathetic control (Sloan *et al.*, 1994; Dishman *et al.*, 2000; Hjortskov *et al.*, 2004; Collins *et al.*, 2005; Lucini *et al.*, 2005; Lucini *et al.*, 2007; Schnell *et al.*, 2013) and this has been found to be the

case amongst workers experiencing high job strain (Van Amelsvoort *et al.*, 2000). This shift can be elicited by alterations in both branches of the autonomic nervous system in opposite directions, (Lucini *et al.*, 2007), by an increase in sympathetic activity, or by a reduction in parasympathetic activity (Dishman *et al.*, 2000; Hjortskov *et al.*, 2004). However, Langelotz *et al.* (2008) reported that heart rate variability was positively correlated with perceived stress levels amongst surgeons during a twenty four hour shift, with both absolute low and high power increasing, causing no change to the low-to-high frequency ratio. Associations between heart rate variability and work ability are not entirely consistent, however. Loerbroks *et al.* (2010) reported that heart rate variability demonstrates a negative association with the effort-reward-imbalance model but no association with job strain as determined by the job-demand-control model. However, Hanson *et al.* (2001) found that heart rate variability was not associated with effort-reward imbalance, although a higher need for control was associated with lower high frequency power. This highlights the potential benefits of adopting physiological assessments of work ability rather than relying upon theoretical models, which cannot be expected to account for the effects that limitless combinations of environmental and psychosocial factors have upon the physical organism.

In addition to, or perhaps more accurately as a result of, sensitivity to the presence of psychosocial stress, heart rate variability is associated with incidence of disease and rates of mortality. Parameters of heart rate variability, in particular a depression in the power of the high frequency band, have been found to be

associated with, and also to predict mortality amongst patients suffering from, cardiac conditions (Cripps *et al.*, 1991; Hohnloser *et al.*, 1997; Ponikowski *et al.*, 1997; Galinier *et al.*, 2000; La Rovere *et al.*, 2003; Stein *et al.*, 2005; Faber *et al.*, 2006). Indeed, the increased mortality rate amongst post myocardial infarction patients suffering from depression has been attributed to a diminished heart rate variability (Carney *et al.*, 2001; Carney *et al.*, 2005). This relationship is not limited to clinical populations, with heart rate variability also demonstrating a predictive power for mortality from cardiovascular disease amongst healthy adult populations (Tsuji *et al.*, 1996; Dekker *et al.*, 2000; Whitsel *et al.*, 2001). Certainly, alterations to autonomic functioning, resulting in vagal withdrawal, can be a risk factor for daily life ischemia (Kop *et al.*, 2001).

Perhaps more interestingly, in the context of work ability, with specific reference to the ability to predict future work ability, is the fact that reduced heart rate variability has been found to precede, and may therefore predict, risk factors for cardiovascular disease, such as hypertension (Liao *et al.*, 1996; Singh *et al.*, 1998; Lucini *et al.*, 2002; Schroeder *et al.*, 2003; Pal *et al.*, 2009) in normal populations. There is also evidence that spectral analysis of heart rate variability is more sensitive to stress than blood pressure measurements (Hjortskov *et al.*, 2004). Significantly, Schroeder *et al.* (2003) reported that the association between heart rate variability and blood pressure is continuous, with important effects occurring even at relatively low blood pressures. Given the well-established association between stress and hypertension, the use of spectral analysis of heart rate variability is likely to provide earlier detection of an elevated

work related strain response than blood pressure monitoring alone (Lucini *et al.*, 2002b). Additionally, there is some evidence to suggest that heart rate variability may be linked to cognitive function which could have significant implications for work ability, although findings are inconsistent at present (Zuli *et al.*, 2005; Kim *et al.*, 2006; Britton *et al.* 2008).

2.6 ASSESSMENT OF WORK-RELATED PSYCHOSOCIAL STRAIN VIA THE CORTISOL AWAKENING RESPONSE

Although there are currently no published findings on whether the cortisol awakening response is associated with the Work Ability Index or the Health and Safety Management Standards, both the job-demand-control model, and the effort-reward-imbalance model have been widely used as a framework to investigate the relationship between work strain and cortisol response. Steptoe *et al.* (2000) reported that average morning cortisol levels were 21.7% higher amongst individuals experiencing high compared to low job strain, as determined by the job-demand-control model. Investigating the two dimensions of the job-demand-control model separately has found the increase in salivary free cortisol over the awakening period to be positively associated with high job demands but not with control (Kunz-Ebrecht *et al.*, 2004a). However, Maina *et al.* (2009a; 2009b) found that the increase in salivary free cortisol over the awakening period was not associated with job strain, but that total amount of cortisol released over the awakening period was. Furthermore, Maina *et al.* (2009b) reported that, whilst the cortisol awakening response is positively associated with job strain measures

of the demand control model it is negatively associated with effort-reward imbalance. Preussner *et al.* (2003b) found the cortisol awakening response to be positively correlated with the 'work overload' scale on the Trier Inventory for Chronic Stress, with there being a significant difference between cortisol levels on waking, and 30 minutes later. These findings are in accordance with those of Schlotz *et al.* (2004) who found that high levels of 'work stress' and 'worry', assessed by the Trier Inventory for Chronic Stress (Schulz *et al.*, 2004), were associated with a greater cortisol awakening response over 30, 45 and 60 minutes post awakening on weekdays but not on weekends. This difference was found to be independent of gender, sleep duration and time of waking.

In contrast to widely used cross-sectional methodologies, adopting an approach to the investigation of the consequences of work that attends to changes in the cortisol response may provide greater information about the extent to which an individual is coping with the demands of work. However, this poses certain challenges; "Researchers have struggled with change detection for many decades" (Fishel *et al.*, 2007; p286). Determining physiological change requires that comparisons be drawn between physiological functioning over at least two time points. The most common method of investigating the physiological response to a particular environment is to compare it with a baseline measure (Stern *et al.*, 2001). Values obtained at rest are typically used as baseline values, with deviation from these values being interpreted as an indication of the extent to which the environment is disturbing the individuals normal functioning. However, in addition to the fact that resting values are often obtained in a rather

unnatural environment, such an approach fails to attend to intra-individual variability in stress reactivity. This clearly poses a methodological challenge for the investigation of psychophysiological processes. An alternative method is therefore to establish a 'vanilla' baseline which involves conducting the baseline assessment in a situation of minimal demand (Jennings *et al.*, 1992).

A common approach used to obtain some form of ecologically valid 'vanilla' baseline with which to compare the effects of work upon the cortisol awakening response is to perform an assessment on a weekend day, presumably on the premise that workdays are inherently more stressful than non-work days. Both Kunz-Ebrecht *et al.* (2004b) and Thorn *et al.* (2006) investigated the influence of work upon the cortisol awakening response by means of a simple comparison of the response on weekdays and weekends. These studies were in agreement that, although there were no differences in the total salivary cortisol response to waking between weekdays and weekend days, there was a significantly greater rise in salivary cortisol following awakening on the weekdays than weekend days. Maina *et al.* (2009a) and Liberzon *et al.* (2008) also reported a more pronounced cortisol awakening response on work compared to non-work days. Although a useful approach, these studies somewhat paradoxically assume that both work days and weekend days are stable in their demands. However, given that the hypothalamic-pituitary-adrenal axis responds rapidly to threat or challenge to maintain homeostasis (Olson *et al.*, 2011) the assumption that the cortisol response represents stable system certainly appears flawed. Nevertheless, studies of the cortisol awakening response in relation to the work environment,

irrespective of the specific work related factor of interest, or the means of quantifying it, seldom attend to potential variance in the response. This may simply reflect the overreliance upon the cross-sectional between-persons approach evident throughout occupational research in general (Johnson *et al.*, 2012), or be indicative of the desire to develop simple assessment methodologies that can easily be adapted for use within organisations to measure employees' wellbeing. As a result, findings are generally limited to the fact that exposure to a certain level of chronic job strain, often expressed in relative terms, i.e. high versus low, is associated with a greater or lower cortisol awakening response (Steptoe *et al.*, 2000; Kunz-Ebrecht *et al.*, 2004a; Alderling *et al.*, 2006; Maina *et al.*, 2009a). Such findings provide support for the involvement of the hypothalamic-pituitary adrenal axis in the relationship between work strain and negative health outcomes, as well as providing evidence of the construct validity of the assessment tools. As a result, at an organisational level, conducting self-report assessments of work strain may help identify areas of work that pose a concern, but provides scant information about the physiological consequences of work for a given individual.

2.7. METHODOLOGICAL CONSIDERATIONS FOR SAMPLING THE CORTISOL AWAKENING RESPONSE

The sampling of the cortisol awakening response is consistently plagued by two issues: determination of the time of awakening and the accuracy of the participant's self-reported compliance with the protocol. Accurately identifying

both the awakening time and the relative timings of all samples is fundamental to measuring awakening cortisol with any degree of confidence. It has previously been demonstrated that delays in excess of 15 minutes between awakening and the initial sampling significantly affect the cortisol awakening response (Okun *et al.*, 2009), but evidence from a recent study (Smyth *et al.*, 2013) suggests that even moderate delays of between 5 and 15 minutes can significantly confound the awakening response. Using objective measurement of awakening time, through electrocardiogram and movement data, Kupper *et al.* (2005) reported that an individual who failed to demonstrate an elevation in cortisol over the awakening period had actually awoken 42 minutes prior to the initial sample, despite reporting no delay between these two events. Whether this resulted from a failure to correctly identify time of awakening, or from inaccurate reporting of sampling time is not clear and is largely irrelevant as both issues of non-compliance similarly affect the outcome. Similarly, Kudielka *et al.* (2007) monitored compliance by means of an electronic monitoring device and found that 43% of participants were non-compliant on at least one of three sampling days. As a result, Almeida *et al.* (2009) assert that investigations of the cortisol awakening response should incorporate the use of both actigraphy and smart-cap salivettes.

An alternative approach is simply to assume that where salivary cortisol fails to increase sufficiently over the awakening period the participant must have been non-compliant (O'Connor *et al.*, 2009). Data is often disregarded from participants who fail to show any increase over the awakening period (Kupper *et al.*, 2005; Thorn *et al.*, 2006) or where the increase is less than 2.5nmol/l (Wust *et al.*, 2000; Maina *et al.*, 2009; Stalder *et al.*, 2011) although the validity of this

cut-off point is questionable, having been extrapolated from serum cortisol in only 6 participants. Indeed the results from a recent study suggest that increases of less than 1.5nmol/l may represent a non-adherent sample (Miller *et al.*, 2013). However, non-normal responses are not always interpreted as being an artefact of non-compliance. Both Dahlgren *et al.* (2009) and Eek *et al.* (2006) observed a high incidence of negative awakening responses but included the data in the analysis presumably considering the response to be genuine, despite not having included an objective measure of compliance. The lack of a standardised methodology appears to have resulted in a position where compliance is either considered in terms of accurate timing of sampling, or in terms of the “normal” response. Wilhelm *et al.* (2007) compared the cortisol awakening response under laboratory conditions and at home, and found that that under the controlled laboratory conditions, without exception, all participants demonstrated a positive awakening response, yet there were a number of negative responses present when samples were obtained by the participants themselves at home. Although not impossible that participants may have perceived the environment of the sleep laboratory to be inherently more stressful than awakening in their home environment, which in turn may have elicited a consistent positive response, it is equally if not more likely that the results are indicative of non-adherence to sampling protocol at home. Additionally, the results from a previous researcher-participant case study found there to be a positive response on all 50 measurement days (Stalder *et al.*, 2009). Although the study did not control for adherence, the authors argue that the use of a participant-researcher design should have afforded a relatively high level of adherence. In order to determine

whether there are any reports of non-positive cortisol awakening responses within the recent literature a mini review was conducted (Table 2.1).

Table 2.1. Recent publications on the cortisol awakening response

Authors	Variables investigated	Timing of samples	Cohort	N	Adherence to protocol controlled?	Incidence of non-positive response	Discarded from analysis?	Findings
Adam <i>et al.</i> (2014)	Onset of anxiety disorder	+40	Adolescents (16.91 years, 171 female)	232	No	Not reported	Not reported	Higher CAR predicted first onset of anxiety
Cullen <i>et al.</i> (2014)	Risk for schizophrenia	+ 15, +30, +60	Children (11-14 years)	91	No	Not reported	Not reported	Blunted CAR may provide early marker for psychosis
Dahlgren <i>et al.</i> (2009)	Sleep, stress, health	+ 15 mins	Office workers	351	No	84 of 351 samples.	+ and - responses analysed separately	Between-individual variation greater than within-individual
De Santis <i>et al.</i> (2010)	Subjective versus objective awakening.	+ 30 mins	Late adolescents	91	Awakening time only	Not reported	Unknown	Higher response amongst objectively assessed adherence.
Engert <i>et al.</i> (2011)	Early life parental care	+ 30 mins	18 – 30 years of age.	58	No	Not reported	Unknown	Lower early life care is associated with greater CAR.
Golden <i>et al.</i> (2014)	Compliance with protocol	+30 mins	Older Adults (65.9 ± 9.8 years, 482 female)	935	Only sample time (smart cap)	Not reported	Analysis attended to degree of non-compliance	Lower compliance associated with lower CAR.
Grant <i>et al.</i> (2009)	Social isolation.	+ 30 mins	Middle aged males	238	Self-report	No	Samples with a delay > 10 mins excluded.	Social isolation and the CAR were positively associated
Griefahn <i>et al.</i> (2008)	Shift work, chronotype	+ 30 mins	19-27 years – males.	16	Yes. Data collected in sleep lab.	Not reported	Awakening > 10 mins prior to sample.	Morning types had higher awakening cortisol.

Griefahn <i>et al.</i> (2010a)	Successive nightshifts	+15, +30, +45, +60.	Students (19 -29 years, 9 female)	18	Yes. Data collected in sleep lab.	Not reported	Awakening > 10 mins prior to sample.	The CAR increased gradually across successive nightshifts.
Griefahn <i>et al.</i> (2010b)	Nocturnal noise	+15, +45	Healthy adults	12 + 46	Yes. Data collected in sleep laboratory.	"Errors" reported.	Awakening > 10 mins prior to sample.	Nocturnal noise affects the cortisol awakening response in vulnerable participants.
Hajat <i>et al.</i> (2010)	Socio-economic status and race	+30	Adults (48-90 years)	935	Only sampling time.	Not reported.	Samples = 0nmol/l or >100nmol/l excluded/	Low SES associated with lower CAR.
Hansen <i>et al.</i> (2010)	Physical activity, job strain	+30	White collar workers (25-67 years, 257 female)	389	No	Not reported	Not reported	Physical activity and job strain did affect salivary cortisol but not over the awakening period.
Hansen <i>et al.</i> (2011)	Workplace bullying	+ 30	White collar workers (1807 female)	2541	Self-report	Not reported	Samples >100nmol/l excluded/	No effect of bullying on the CAR.
Hewig <i>et al.</i> (2008)	Exam stress	+30, +45, +60.	Undergraduate students (20-30 years, 31 female)	37	No	Not reported	Not reported	No effect of exam stress on the CAR.
Hill <i>et al.</i> (2013)	Personality Traits	+30, +45.	Adults (18-78 years, 49 female)	107	Self-report	Not reported	Not reported	Extraversion positively associated with the CAR.
Izawa <i>et al.</i> (2010)	Autonomic nervous system activity	+30, +45, +60	Students (mean age 23.4, 8 female)	20	No	Not reported	Not reported	Sympathetic activity was associated with the CAR.
Johnson <i>et al.</i> (2014)	Psychopathy, empathy, aggression	+30	Young adults (19.07 ± 1.33 years, 25 female)	57	No	Not reported	Not reported	CAR provides a biological index of psychopathic personality traits
Karlson <i>et al.</i> (2011)	Work stress	+45	Employees	383	No	Not reported	Not reported	↓ job control was associated with higher CAR

Kidd <i>et al.</i> (2014)	Lab stress v naturalistic	+30	Healthy adults	466	Yes	Yes	delay > 10 mins.	Cortisol responses to lab stress were associated with CAR
Kumari <i>et al.</i> (2009)	Sleep duration, sleep quality	+30	Middle aged civil servants	2751	Self-report	Not reported	Awakening > 10 mins prior to sample	Short sleep was associated with greater CAR
Lai <i>et al.</i> (2010)	Humour	+15, +30, +45	Older men (64-86 years)	45	Electronic alarm.	Not reported	Not reported	Humour was negatively associated with total cortisol over the awakening period.
Liberzon <i>et al.</i> (2008)	Naturalistic stress	+30, +45	Novice sailors (18 female)	31	No	Yes	Not reported	Stress was associated with a greater CAR.
Liu <i>et al.</i> (2014)	Self-esteem	+30	Older adults (60+ years)	147	No	Not reported	Not reported	CAR unaffected by change in self-esteem
Lovell <i>et al.</i> (2011)	Perceived Stress	+30	Female students	35	Self-report	Not reported	Delay > 60 mins between awakening and +30 mins sample	Stress did not affect the CAR.
Maina <i>et al.</i> (2009)	Job strain	+30, +60	Call centre workers (89 female)	121	Self-report	Not reported	CAR < 2.5 nmol/l	Job strain was positively associated with the CAR.
Marchand <i>et al.</i> (2014)	Burnout (work-related)	+30	Day-shift workers (41.3 ± 10.8 years, 225 female)	401	No	Not reported	Not reported	Emotional exhaustion and a global burnout average were associated with low CAR
Mayes <i>et al.</i> (2009)	Experimental pain	+30 +45	Healthy adults (40 female)	80	Self-report	Not reported	Not reported	Pain was associated with lower CAR.
Mikolajczak <i>et al.</i> (2010)	Psychological factors	+15, +30, +45, +60	Healthy male workers (30-50 years)	42	No	Not reported	Not reported	Protective psychological factors are associated with a flexible CAR.

Moriarty <i>et al.</i> (2014)	Spatial working memory	+15, +30, +45, +60	Adult males (30-60 years)	19	No	Not reported	Not reported	CAR demonstrates a U shaper relationship with spatial memory
O'Connor <i>et al.</i> (2009)	Psychological Stress	+15, +30, +45	Female adult (40-60 years)	118	No	29 participants had CAR <2.5 nmol/l	CAR < 2.5 nmol/l	High stress associated with lower CAR.
O'Donnell <i>et al.</i> (2008)	Psychological coping	+30	Civil servants (192 female)	542	No	Not reported	Delay > 15 mins between awakening and sample	No associations between coping and the CAR.
Okun <i>et al.</i> (2010)	Sampling adherence	+30	Older adults (60 + years, 133 female)	207	Partially monitored in sleep lab	Yes (CAR ranged from -16.6 to 51.6)	Delay > 10 mins.	Self-report reflects objective measures of adherence.
Randler and Schaal (2010)	Chronotype	+30	Adolescents and students (13-39 years, 93 female)	125	No	Not reported	Not reported	Morning types had higher cortisol on awakening.
Ross <i>et al.</i> (2014)	Stability of CAR	+30	147 adolescent girls - 47 middle aged adults	147 + 47	Self-report	Not reported	Sample > +20 mins from protocol	Most of the variation in CAR reflects day-to-day differences.
Rotenberg and McGrath (2014)	Adherence	+30, +45	Healthy children and adolescents (8 – 18 years)	201	Only awakening via actigraphy	Not reported	Analysis correlated delay with CAR	Sampling delay and time of awakening influenced the CAR.
Shin <i>et al.</i> (2011)	Determine normative values	+30	Healthy workers (20-59 years, 74 female)	133	No	21 had CAR <2.5nmol/l	CAR < 2.5 nmol/l	

Slatcher <i>et al.</i> (2010)	Work worries	+45	37 married couples	74	Self-report	Not reported	Not reported	
Smyth <i>et al.</i> (2013)	Adherence	+5, +10, +15, 20, +25, 30, +45	(1) 50 healthy females – (2) 20 researchers	50 + 20	Actigraphy and smartcap	Mean decrease from 0-5 mins	Delays of various duration	Delays of 5-15 mins between awakening and initial sample result in erroneous CAR.
Stalder <i>et al.</i> (2010)	Psychosocial variables	+45	12 females (22-41 years)	12	Only awakening via actigraphy	CAR <2.5 nmol/l on 23.4% of samples	>10 mins. But unclear re CAR <2.5nmol/l	Intra-individual analysis showed variation in state stress to be associated with CAR.
Stalder <i>et al.</i> (2011)	Heart Rate Variability	+15, +30, +45	38 students (18-40 years, 28 female)	38	Only awakening via actigraphy	CAR <2.5nmol (15.8% n.a 10.8% a.	>10 mins.	No association between CAR and HRV over the awakening period.
Storetvedt and Garde (2014)	Occupational rehabilitation	+30	Adults in vocational rehabilitation	17	No	Not reported	Not reported	CAR may reveal effect of intervention in a rehabilitation clinic
Teismann <i>et al.</i> (2013)	Rumination, Mood	+30	68 (18-49 years, 40 female)	68	Not reported	Not reported	Not reported	Writing about life goals reduced rumination and the CAR.
Thorn <i>et al.</i> (2011)	Seasonal affective disorder (SAD)	+15, +30, +45	Adults with and without SAD (26-75 years, 34 female)	52	Not reported	Not reported	Not reported	No seasonal change in healthy subjects. Attenuated CAR in winter in SAD subjects.
Vammen <i>et al.</i> (2014)	Depression in public sector employees	+30	Public sector employees	2408	Not reported	Not reported	Not reported	Salivary cortisol was not associated with depression.

Vargas <i>et al.</i> (2014)	Sleep, stress	+30, +45, +60	Students (18.7 ± 9.1 years, 29 female)	58	Not reported	Not reported	Not reported	No effect of stress on CAR. ↓sleep = ↑ CAR
Walker <i>et al.</i> (2014)	Trait anxiety	+15, +30, +45	Students (24.4 ± 7.06 years, 26 female)	40	Self-report	5 subjects showed no ↑	Yes	CAR is influenced by trait anxiety.
Wolfram <i>et al.</i> (2011)	Menstrual Cycle	+30, +45, +60	Healthy females (20 -34 years)	29	Self-report	Yes	>15 mins	Elevated CAR during ovulation
Zoccola <i>et al.</i> (2011)	State v trait preservative cognition (PC)	+30, +45, +60	Students (20.8 ± 4 years, 71 female)	119	Awakening actigraphy	Not reported	Not reported	No effect of trait PC, prior night's state PC associated with CAR.

N denotes sample size. CAR: cortisol awakening response, HRV: heart rate variability na: non-adherent, a:adherent

Of the 48 studies included, 23 provided no information as to whether they included a measure of compliance, 11 relied upon self-report, 5 controlled for awakening time, and 2 controlled for sampling time only. There were 3 studies which monitored adherence with both awakening and sampling time, although these were performed in a sleep laboratory by the same researcher. In terms of the normality of the response, 35 studies failed to provide sufficient detail to determine whether there had been any responses that could be considered non-normal by any criteria. A total of 12 studies reported the presence of a non-normal response: 4 were due to the increase being less than 2.5 nmol/l, whilst 2 were due to no rise, or a negative response, and the remainder were unclear as to what was considered non-compliant. However, none of these studies had adequately controlled for compliance. There were 19 studies which provided criteria which would lead to samples being disregarded (although not all gave sufficient detail to determine whether this led to any samples being excluded or not). Of these, 9 had exclusion criteria of a delay in excess of 10 minutes, 2 where the delay exceeded 15 minutes, whilst one study deemed delays greater than an hour between awakening and sampling to represent non-compliance. There were 2 studies which disregarded samples where salivary free cortisol was in excess of 100nmol/l and, 3 studies excluded samples where the increase over the awakening period was less than 2.5 nmol/l as an exclusion criterion. In summary there none of the studies detailed in Table 2.1 identified the presence of any non positive cortisol awakening responses where bot awakening time and sampling time had been adequately controlled.

There is also substantial variation in the timing of sampling in much of the existing literature. Although samples are most frequently obtained 30 minutes post awakening, with additional samples at 45 and 60 minutes post awakening being common, some studies have obtained samples at 20 minutes (Lai *et al.*, 2005; Nicolson and Diest, 2000) or 40 minutes (Lai *et al.*, 2005) post awakening. This apparently arbitrary selection of sampling times certainly does nothing to further understanding of the response.

Given the nature of the response, i.e. that it corresponds to the period of sleep inertia, the possible influences of sleep-related factors upon the response have been investigated. Several studies have reported there to be no association between the cortisol awakening response and the time of awakening (Preussner *et al.*, 1997; Wüst *et al.*, 2000b; Kunz-Ebrecht *et al.*, 2004b; Schlotz *et al.*, 2004) supporting the contention that the cortisol awakening response is unaffected by the diurnal nature of the hypothalamic-pituitary-adrenal axis, whilst others have found that earlier awakening is associated with a greater cortisol awakening response (Edwards *et al.*, 2001; Kudielka and Kirschbaum, 2003; Federenko *et al.*, 2004a; Williams *et al.*, 2004; Almeida *et al.*, 2009; Mikolajczak *et al.*, 2009; Stadler *et al.*, 2009; Stadler *et al.*, 2010). Similarly, it has been shown that the cortisol awakening response is unrelated to sleep quality (Mikolajczak *et al.*, 2009; Stadler *et al.*, 2009; Stadler *et al.*, 2010) or sleep duration (Wüst *et al.*, 2000; Stadler *et al.*, 2010). However, Schlotz *et al.* (2004) reported that shorter periods of sleep, or poorer sleep quality, result in a slightly greater cortisol awakening response. A study by Williams *et al.* (2004) may, however, provide an insight into the potential cause of these discrepant findings by suggesting that

greater levels of stress often accompany earlier awakening. The study found that whilst greater increases in the cortisol awakening response occurred on early shift days compared to day shift, this was associated with participants reporting greater levels of stress in the hour after waking, and also with greater sleep disturbance the previous night. In fact, once the differing levels of stress post awakening and the variance in quality of sleep were accounted for there was no longer a difference in cortisol awakening response between experimental conditions. As a result, the increased cortisol awakening response which is often found to be associated with earlier awakening may not be diurnal in origin, being instead representative of the increased stress associated with earlier awakening.

Despite widespread use as a marker of psychosocial stress, the cortisol awakening response remains something of an unknown quantity. The exact function of the cortisol awakening response and the mechanisms responsible for the phenomenon are still to be fully elucidated (Fries *et al.*, 2009). It is also unclear whether a more pronounced response or an attenuated one poses more of a risk to health, and there is no consensus as to what a “normal” cortisol response to awakening actually looks like (Mikolajczak *et al.*, 2010). A possible explanation for the current position lies in the lack of published guidelines for sampling of the cortisol response and the lack of standardised experimental protocol for the assessment of the response.

2.8 THE DYNAMIC WORKPLACE: INTRA-INDIVIDUAL VARIATION

Investigations of autonomic function in the workplace have almost exclusively considered the work environment to be temporally stable, and this is reflected in the use of traditional cross-sectional, between-subjects designs. Studies frequently measure physiological markers such as heart rate variability and blood pressure within different cohorts of employees at a single time point and attempt to draw conclusions about the inherent levels of strain present in their work according to the between-individual variance in cardiovascular and autonomic functioning. However, this is not restricted to investigations of psychophysiology and applies equally to self-reported work strain. Indeed, Johnston *et al.* (2013) state “Virtually all studies of occupational stress have examined the differences in stress and its determinants between people and attempted to determine, for example, whether people in high strain occupations or who perceived their work to have many demands or low control or reward report more stress and experience more ill health” (p. 3). Whilst this approach has undoubtedly provided valuable insights into the relationship between work and health, the work domain is inherently dynamic and, by its very nature, the between-persons approach limits our ability to understand the dynamic processes underpinning work itself and our responses to it. These limitations were recently highlighted by Uchino *et al.* (2012) in their review bearing the ‘novel’ title “*Psychological pathways linking social support to health outcomes: A visit with the “ghosts” of research past, present, and future*’.

Although, in certain situations characteristics may pertain not only to population variation but also to the individual persons in the population (Cervone, 2005) the application of findings obtained using a between-individual methodology to an individual and vice-versa is inherently flawed, operating on the incorrect assumption that the within-subject and between-subject dimensions are always equivalent (Borsboom *et al.* 2003). Therefore, generalising from inter-individual findings to an individual should be avoided (Hamaker *et al.*, 2005; Molenaar & Campbell, 2006). Fortunately, researchers are increasingly beginning to acknowledge the importance of temporal variance, both in job characteristics (Totterdell, 2006) and their cognitive and affective correlates (Ilies & Judge, 2002; 2004). Indeed, the paradigm appears to be shifting from a position where variance between individuals was merely considered undesirable noise within the data to a new standpoint which addresses this meaningful within-person variability. Molenaar and Campbell (2006) sum up the importance of this new person-specific paradigm by stating that “Given the finding that inter-individual variation often cannot be equated to intra-individual variation, the dedicated study of intra-individual variation is, in view of the classical ergodic theorems, no longer an option, but a necessity” (p.116).

The results from a daily diary study of job characteristics and home life demonstrated that a significant proportion of the total variation in perceived demand (63%) was accounted for by within-person variation (Butler *et al.*, 2005). Additionally, the findings of a 26 week test of intra-individual variation in the job-demands model suggest that intra-individual variations in demand and control are of a similar magnitude to between-person variations (Totterdell *et al.*, 2006). It

has been suggested that perceived demand is analogous to workload; “In our view, daily workload is a subjective construct reflecting an employee’s perceived work demands on a particular day” (Ilies *et al.*, 2010 p.409). It is perhaps unsurprising; therefore, that daily workload also exhibits substantial variation from day to day (Sonnentag & Bayer, 2005; Ilies *et al.*, 2007; Ilies *et al.*, 2010).

Several studies have now attempted to quantify the amount of variance accounted for by within-individual variation, in multiple work related measures. One study, of 27 employees who completed mood and satisfaction surveys four times a day for four weeks found that 36% of the total variation in job satisfaction was accounted for by within-individual variation (Ilies & Judge, 2002). Another, similar, study reported that 56% of the variance in the hedonic tone of mood at work was found to be down to within-person rather than between person variance (Miner *et al.*, 2005). Sonnentag (2003) reported that at least 40% of the variance in work engagement, measured over 5 days, was within-individual and 74% of variance in ‘flow’, or optimal experience, at work has been shown to be situational rather than dispositional, and related to mood (Fullager & Kelloway, 2009). Ilies *et al.* (2010) who examined within-individual relationships between workload and distress reactions because these reactions represent the most immediate effects of job demands, found that workload was positively associated with affective distress, blood pressure and with indicators of low daily well-being.

Relationship conflict at work has been shown to be associated with angry mood (Meier *et al.*, 2013) and the frequency of stressful events within a working week

has been demonstrated to be positively related to negative affect at the end of the week (Potter *et al.*, 2002). Within-person investigations have also shown that high demand, allied to low control, predict negative affect (Johnston *et al.*, 2013). Similarly, workload has repeatedly been shown to demonstrate a positive association with negative affect (Guerts *et al.*, 2003; Totterdall *et al.*, 2006; Zohar *et al.*, 2003) and this is true for both objectively measured workload and perceived workload (Ilies *et al.*, 2007). Therefore, self-reported variance in perceived demand, which provides a surrogate measure of workload, should be associated with work-related affect. In their paper, on daily psychosocial demands and cardiovascular risk, Kamark *et al.* (2005) show that changes in daily experience result in significant within-person changes in heart rate and blood pressure. Similarly, Ilies *et al.* (2010) found daily levels of negative affect to be associated with blood pressure over a ten day period. Taken together, this evidence highlights the importance of adopting a within-persons approach to the study of the psychophysiological response to the work environment.

2.9 SUMMARY OF REVIEW AND GAPS IN THE LITERATURE

This section provides a brief summary of the main points identified within this literature review, highlights the gaps in the existing literature and details how this thesis intends to address them.

2.9.1 Summary of Literature Review

- Exposure to occupational strain has been associated with negative health consequences, particularly cardiovascular disease.

- Various models have attempted to describe the factors that contribute the experience of job strain. The interaction between job demand, autonomy, support and resources, as well as the balance between job related effort and reward are the most widely reported influences upon job strain.
- The Work Ability Index appears to be associated with health status. However, as this may be largely due to the measures of current health status contained within the Index the predictive power of the index to identify employees at risk of ill health is less clear.
- The Health and Safety Management Standards Indicator Tool is based upon a risk assessment methodology. Rather than attending to the interactive effects of environmental and personal factors, this approach assumes that each of the individual standards can pose a risk to health. Although the Management Standards have been associated with psychosocial stress and anxiety, no attempt has been made to investigate the physiological consequences of work using the Management Standards Indicator Tool.
- Ambulatory blood pressure monitoring is a widely used tool for investigating physiological reactions to naturalistic situations. There is evidence to suggest that exposure to job strain is associated with ambulatory blood pressure.
- Ambulatory heart rate variability provides a readily assessable measure of autonomic functioning and has been widely used to investigate job strain. Job strain has generally been shown to be associated with a reduction in

time domain parameters of heart rate variability and with a shift towards sympathetic dominance in spectral parameters.

- Salivary free cortisol demonstrates a marked increase over the period immediately following awakening which is believed to be related to anticipatory processes. There is evidence to suggest that the cortisol awakening response is associated with job strain.
- Stress reactivity appears to demonstrate substantial between-person variability.
- The workplace appears to be a dynamic environment with variable characteristics. There is evidence of substantial within-individual variation in environmental factors including job demands, job control, workload, but also in psychosocial factors such as affect, job satisfaction and wellbeing.

2.9.2 Gaps in the existing literature

This review has identified a number of gaps in the current literature. These are detailed below with along with information about how this thesis will address these.

- Reported use of the Health and Safety Management Standards Indicator Tool is rather limited at present and there are no reported investigations of the psychophysiological response to work using the Health and Safety Management Standards Indicator Tool. By using the Indicator Tool to conduct an assessment of psychosocial hazard amongst higher education employees and integrating this into psychophysiological

approach by performing ambulatory physiological monitoring this thesis will help to address both of these gaps.

- There is a scarcity of literature addressing the extent to which psychophysiological responses vary in response to the changes in the acute working environment at the intra-individual level. This thesis intends to provide information about the physiological responses occurring within the context of a dynamic working environment at the within individual level.
- There is an absence of studies which have included adequate control over the sampling of the cortisol awakening response within the occupational literature. Theoretically, there exists a trade-off between ecological validity on one hand and internal validity on the other, when studies are performed in the field (Fahrenberg, 1996). Nevertheless, the pursuit of ecological validity should not absolve researchers of the responsibility for ensuring that some degree of internal validity remains. Whilst sampling of the cortisol awakening response in the naturalistic environment is inherently high in ecological validity, in order for valid inferences to be drawn about the response of cortisol upon awakening, compliance with the sampling protocol is paramount. However, despite Almeida *et al.* (2009) making a similar claim previously, the issue of compliance is largely overlooked, or given insufficient consideration. Reliance upon self-reported compliance is common, yet this arguably does little to enhance internal validity. The most rigorous approach involves objective measures of both awakening and sampling times, usually via the use of accelerometers and electronic bottles. By controlling for both time of awakening and sampling times this

thesis should produce results which reflect the genuine awakening response only.

- It remains unclear whether low levels of physical activity, as could be expected to occur in the performance of relatively sedentary occupations, might influence ambulatory heart rate variability. As this could have significant implications for the validity of ambulatory assessment during working hours this thesis will investigate the relationship between concurrent worktime physical activity and ambulatory heart rate variability through use of electrocardiogram and accelerometry.

2.9.3 Aims and Objectives

This thesis has two main aims: To investigate the psychophysiological consequences of work among higher education employees, and to investigate the practical application of a methodology combining psychosocial and ambulatory physiological assessments. The following objectives have been identified:

- Perform both psychosocial and ambulatory physiological assessments over multiple days to investigate the importance of acute work-related factors. More specifically, to investigate ambulatory heart rate variability, blood pressure and the cortisol awakening response on work days containing differing levels of acute demand.
- Investigate some of the practical and methodological issues associated with assessment of both the cortisol awakening response and ambulatory heart rate variability.

CHAPTER 3. General methods

3.1 INTRODUCTION

This chapter outlines the general methods used in the collection and analysis of data used in this thesis. The data was collected from two independent experimental studies and any important differences in methodology will be outlined briefly. Specific methods of data collection and analysis can be found in the methods section of the relevant chapters. The general methods are presented in five sections. Section 2.2 provides information on the recruitment of participants. Section 2.3 provides detail of all equipment used in the collection and analysis of both physiological and psychosocial data. Section 2.4 outlines the experimental protocols used, whilst Section 2.5 details the approach taken to both data handling and statistical analysis.

3.2 PARTICIPANT RECRUITMENT

3.2.1 Study one

Participants for the first study were recruited from staff at Edinburgh Napier University via an advertisement placed on the staff intranet and email. Inclusion criteria were that participants had to be employed on a permanently contracted basis and working a minimum of 25 hours per week; as this exceeds 50 percent of the maximum weekly working hours set down in the Working Time Regulations (1998) it is likely to constitute the participant's primary employment. Exclusion criteria were: smoking; alcohol consumption in excess of weekly recommended limits of 21 units for males and 14 units for females respectively; use of medication which could affect blood pressure or heart rate dynamics; and a diagnosed medical condition which could affect cardiovascular or respiratory

function. Recruitment was deliberately restricted to a single institution in to eliminate the potential for inter-organisational differences to confound findings, e.g. different organisational structures, working environments and job characteristics. This resulted in twenty participants (13 male, 7 female) volunteering to participate in the study. All participants were provided with a written information sheet, given the opportunity to ask questions about the study and made aware that they could withdraw from the study at any point prior to providing written informed consent. Approval for the study was obtained by the Research Ethics Committee of Edinburgh Napier University's Faculty of Health, Life and Social Sciences (Appendix I).

3.2.2 Study two

As a single case study a researcher-participant design was used for the second study, no recruitment was required. Approval for the study was obtained by the Research Ethics Committee of Edinburgh Napier University's Faculty of Health, Life and Social Sciences (Appendix II). The participant was required to sign a disclaimer to the effect that they understood what the protocol demanded of them, were aware of the risks, had not been coerced in any way and fully absolved the University from all responsibility for any harm to their wellbeing resulting from the study. The participant was a 36 year old non-smoking healthy male (height-180cm, mass-76kg), who was free from use of any medication. The participant was a self-funding PhD student, who was contractually employed to work 14.5 hours per week as an academic adviser at Edinburgh Napier University. Additionally, the participant was also employed to provide ad-hoc support to students with specific learning requirements and, as a result, followed a normal 9-5 working pattern during the week.

3.3 EQUIPMENT

This is a comprehensive description of all the equipment that was used within the collection and analysis of data. The following chapters will provide information of when specific equipment was used.

3.3.1 *Cardiotens monitor and software*

The Cardiotens combined electrocardiogram and ambulatory blood pressure monitor is a small (124 x 82 x 33.5mm), lightweight (238g) ambulatory diagnostic device (Figure 3.1). The monitor can detect blood pressure within the range of 30-260mmHg, with an accuracy of ± 3 mmHg, or 2% of the measured value. The device offers real time monitoring for optimal electrode placement and can store 24 hours' worth of electrocardiogram data. Heart rate variability analysis is based upon the Meditech electrocardiogram processing algorithm which has 99.8% beat detection accuracy.



Figure 3.1 Cardiotens monitor (Meditech, 2011).

Spectral analysis of HRV was performed using Cardiovisions software (Meditech, Hungary) which utilises a Fast Fourier Transformation. The raw data was visually inspected and noisy artefacts manually removed. The period of ambulatory recording was manually selected and spectral analysis of HRV was performed for both low (0.04-0.15 Hz) and high (0.15-0.4 Hz) frequency bands (Figure 3.2). Half hourly blood pressure readings were also obtained from the same software. The average duration of recording was 421 ± 39 minutes.

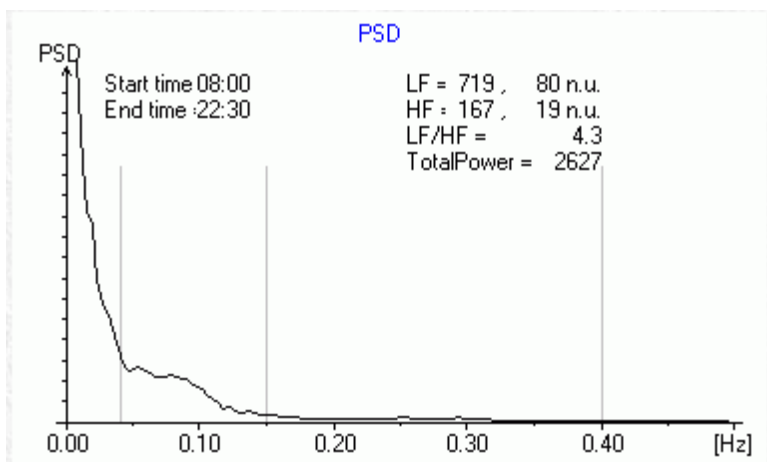


Figure 3.2 Example of Cardiovisions output

3.3.2. Actiheart monitor and software.

Activity level during the working day was monitored using an Actiheart combined HR and movement monitor (Cambridge Neurotechnology Ltd, Papworth, UK) in short-term mode, recording movement counts in 15s epochs. The Actiheart is a compact, lightweight (<10g) chest worn combined electrocardiogram and activity monitor (Figure 3.3) The device, which is waterproof and can be used during everyday activities, attaches directly to standard electrocardiogram electrodes via two clips. The Actiheart has a range of 30 – 250 beats per minute, a sampling frequency of 128 Hz, and can record 440,000 beats. The Actiheart has been

shown to be suitable for use as a stand-alone ambulatory method for heart rate variability monitoring during occupational and leisure-time activities (Kristiansen *et al.*, 2011) and a detailed description of the monitor, including technical reliability and validity, is available elsewhere (Brage *et al.*, 2005).



Figure 3.3. The Actiheart monitor

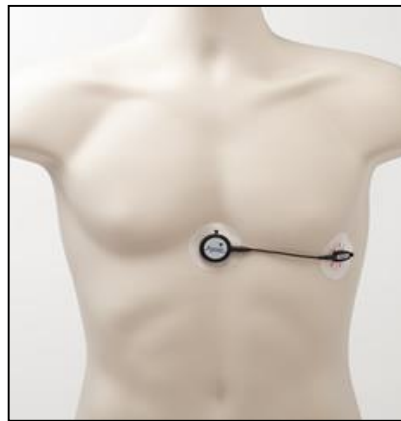


Figure 3.4. Typical Actiheart placement

Data was transferred to Actiheart software version 4.0.33 (CamNTEch, Cambridge, UK) using the combined reader/charger. The analogue signal was band-pass filtered (10-35 Hz), sampled with a frequency of 128 Hz, and processed by a real time QRS-detection algorithm (Actiheart User Manual, 1999). The statistics calculated by the Actiheart software are based on the recommendations of the Task Force of the European Society of Cardiology and the North American Society of Pacing and Electrophysiology (1996). Data was then exported to Microsoft Excel and any data flagged as being invalid was removed prior to analysis. The average duration of recording was 421 ± 39 minutes.

3.3.3 Medication event monitoring system

An objective measure of the timing of all saliva samples was obtained using an electronic monitor (Medication Event Monitoring System; MEMS, Aardex group Ltd, Switzerland) (Figure 3.5). The monitoring system is comprised of two parts: a standard plastic vial with threaded opening and a closure for the vial containing a micro-electronic circuit that registers dates and times when the closure is opened and when it is closed. The MEMS device has a clock precision of ± 30 s per month (Aardex, 2005) and has been shown to have perfect functioning i.e. 0% missing registrations and 0% over-registrations (De Blesser *et al.*, 2010).



Figure 3.5. Medication Event Monitoring System (Ardex, 2005)

3.3.4 Salivette collection system

Saliva samples were collected using the Salivette collection system (Salimetrics, Newmarket). The Salivette system comprises inert polymer cylindrical swabs and polypropylene collection tubes and vials (Figure 3.6). The average saliva recovery rate is almost 100% irrespective of cortisol concentration or saliva

volume and the average volume recovered in $1.1 \pm 0.3\text{ml}$ in adult samples (Sarstedt, 2010.)



Figure 3.6 Saliva swab and storage tube.

3.3.5 Salivary cortisol enzyme immunoassay.

Salivary free cortisol concentrations were measured using a commercially available enzyme linked immunosorbent assay kit (Salimetrics, Newmarket). The assay kit contains: a 96-well microtitre plate coated with monoclonal anti-cortisol antibodies, cortisol standards, cortisol controls, wash buffer concentrate, assay diluent, cortisol enzyme conjugate, tetramethylbenzidine substrate solution, sulphuric acid stop solution and non-specific binding wells. The assay has a range of $0.012\text{-}3.000\mu\text{g/dl}$ and a sensitivity of $<0.007\mu\text{g/dl}$.

3.3.6 The Work Ability Index

The Work Ability Index (Appendix III) is a self-assessment tool which was designed to determine how effective workers are, at present, and likely to be in the near future, in order to maintain, or promote, the work ability of employees (Ilmarinen, 2007). The Work Ability Index comprises a total of seven questions which are all intended to assess specific factors that are believed to contribute

towards workability. The first question requires respondents to provide a rating of their current workability in relation to their lifetime best on a 7 point scale, whilst question two addresses physical and mental workability separately. Question three focuses on the presence of any existing medical conditions and requires respondents to state whether they suffer from any of 50 different medical conditions. Question four addresses possible work impairment while question five relates to incidence of sick leave in the preceding 12 month period. The final two questions relate to predicted future workability and mental resources. Scoring of the Work Ability Index provides a single score that is then used to establish which categorical rating of workability applies to the respondent: “poor” (2-27), “medium” (28-36), “good” (37-43), and “very good” (44-49). This score relates to the individual’s ability to perform their current job, rather than providing a more global measure of workability and the scoring is weighted to reflect the nature of the job| i.e. mental of physical.

3.3.7 The Management Standards Indicator Tool.

The Health and Safety Executive’s Management Standards Indicator Tool (Appendix IV) is a 35-item questionnaire relating to the six primary stressors identified in the Management Standards approach to tackling Work Related Stress (Health and Safety Executive, 2005). The Indicator Tool quantifies the following dimensions of work strain: Demands (workload, work pattern work environment); Control (autonomy over working practices); Managerial Support (encouragement and resources); Peer Support (colleague encouragement and support); Relationships (positive working, avoidance of conflict); Role

(understanding of role or clarity, non-conflicting roles); and Change (how effectively is change managed and communicated). Participants indicate the extent to which various statements reflect their experiences at work over the preceding six month period, for example “I have a choice in deciding how I do my work” and “I have to work very intensively”. Responses are provided on a 5-point scale: 1 (never), 2 (seldom), 3 (sometimes), 4 (often) and 5 (always). The Indicator Tool has a high level of reliability, with a goodness of fit index of 0.92 (Edwards, Webster, Van Laar, & Easton, 2008), and Chronbach’s alpha values ranging from .78 to .87 for individual scales (Cousins *et al.*, 2004). The Management Standards Analysis Tool (Health and Safety Executive, 2007) is an Excel based tool designed to be used with the Indicator Tool. The Analysis Tool enables comparison with the Health and Safety Executive’s benchmark data.

3.3.8. The Positive and Negative Affect Schedule.

Affect was measured using the short version of the positive and negative affect schedule (PANAS; Watson *et al.*, 1998; Appendix V). The PANAS is a 20 item measure comprising two mood scales, one measuring positive affect and the other measuring negative affect. Participants are required to indicate how they are feeling at that moment in time by rating the extent to which each word describes their current state. Example positive affect items include “interested” and “enthusiastic”, and negative items include “upset” and “afraid”. Responses are provided using a 5 point Likert scale ranging from 1 = *very little, or not at all*, and 5 = *extremely*. Each scale therefore has a range of scoring from 5-50, with

higher scores representing more positive or negative affect, respectively. Both the positive and negative affect scales have high levels of reliability with Cronbach's alpha values of .89 and .85 respectively having been reported (Crawford and Henry, 2004).

3.3.9 Visual Analogue Scale

Perceived work-related demand was measured by means of a visual analogue scale (Appendix VI), as this method has previously been shown to provide a meaningful and useful assessment of occupational stress (Lesage & Berjot, 2011). The scale had a range of 100mm and was anchored at the midpoint by the term 'average demand', whilst 0mm and 100mm were labelled as representing "not at all" and "very" demanding days respectively. Scores obtained from the scale were divided by a factor of ten, providing a range from 0-10 and were then used to differentiate between the demands of the two days at an intra-individual level.

3.3.10. Workload Questionnaire

Workload was measured using an 8 item questionnaire (Appendix VII) that has previously been used in repeated measures studies investigating the influence of workload (Ilies *et al.*, 2007; Ilies *et al.*, 2010). Respondents rate the extent to which various statements represent their working environment at that particular moment in time. An example item is "At the present moment to what extent do you: 'have to work fast', 'have to deal with a backlog'. Responses are given using a 5 point Likert scale ranging from 1 = *highly disagree* to 5 = *highly agree*. Possible scores therefore range from 8 to 40, with higher scores representing the

presence of a greater work load. The four momentary workload scores were aggregated to provide a mean daily workload score.

3.4. PROCEDURES

3.4.1 Salivary cortisol sampling and analysis

Participants were instructed not to brush their teeth prior to the collection of both samples to avoid potential contamination from blood. Additionally, the consumption of food or drink, with the exception of water, was prohibited until after the second sample had been obtained. Immediately prior to saliva collection, participants were required to tilt their head forward for 30 seconds to allow saliva to pool behind the lower front teeth. The inert polymer cylindrical swabs (Salimetrics, Newmarket) were placed under the tongue for 1 minute and then stored in Salivette collection tubes (Salimetrics, Newmarket). Workday samples were taken to the laboratory on the day of collection. Weekend samples were stored in the participant's home freezer and delivered to the laboratory on the next working day and immediately frozen at -20°C.

To enable analysis, all reagents, microtitre plates and saliva samples were brought to room temperature. The wash buffer was then prepared by diluting the concentrate with room temperature deionized water: 100ml of wash buffer concentrate to 900ml of deionized H₂O. Then 24ml of assay diluents was added to a disposable tube using a pipette and set aside for later use. Once at room temperature, saliva samples were centrifuged at 3000 rpm for 15 minutes. 25µL of standards, controls and unknown saliva samples were then mixed and added

to the appropriate wells in duplicate (Figure 3.7). 25 μ L of assay diluent was then added to the zero and non-specific binding wells. Then a 1:1600 dilution of the conjugate was made by adding 15 μ L of conjugate to the 24ml of assay diluent previously prepared. 200 μ L of this solution was then added to each well using a multichannel pipette (Eppendorf, Stevenage, UK). The plate was then mixed at 500rpm for 5 minutes on a microplate shaker (Vibramax 100, Heidolph, Germany) before being incubated at room temperature for 55 minutes. The plate was then washed by gently squirting the diluted wash buffer into each well with a squirt bottle, draining the wells by inverting the plate over a sink, and then blotting on paper towel. This process was performed 4 times in total. 200 μ L of tetramethylbenzidine solution was then added to all wells and the plate was mixed at 500rpm for a further 5 minutes. The plate was then incubated in the dark at room temperature for 25 minutes after which point 50 μ L of sulphuric acid stop solution was added to all wells with a multichannel pipette and the plate was mixed once more at 500rpm for 5 minutes. The bottom of the plate was then wiped with a moist cloth and dried before being read in a plate reader (Dynex, West Sussex, UK) at a wavelength of 450nm. Cortisol concentrations were calculated using a 4-parameter non-linear regression curve. Salivary free cortisol values were then converted from μ g/dl to nmol/l by applying a multiplication factor of 27.59 (Young, 1987).

	1	2	3	4	5	6	7	8	9	10	11	12
A	3.00 std	3.00 std	Ctrl - H	Ctrl - H								
B	1.00 std	1.00 std	Ctrl - L	Ctrl - L								
C	.333 std	.333 std	Unk - 1	Unk - 1								
D	.111 std	.111 std	Unk - 2	Unk - 2								
E	.037 std	.037 std	Unk - 3	Unk - 3								
F	.012 std	.012 std	Unk - 4	Unk - 4								
G	Zero	Zero	Unk - 5	Unk - 5								
H	NSB	NSB	Unk - 6	Unk - 6								

Figure 3.7. Plate layout for salivary cortisol assay.
 std: standard, Unk: unknown, Ctrl – H; high control, Ctrl – L, Low control, NSB: Non-specific binding wells.

Absolute measures of salivary free cortisol were determined as the concentration of cortisol (nmol/l) present in saliva samples on awakening; 30 minutes post awakening; and 45 minutes post awakening (where applicable). To provide a summary measure of the repeated measures of salivary free cortisol obtained in the single-participant case study the area under the curve was also calculated both with respect to ground and increase (Figure 3.8). The area under the curve with respect to ground provides a measure of total hormonal output while the area under the curve with respect to the increase reflects the sensitivity of the system.

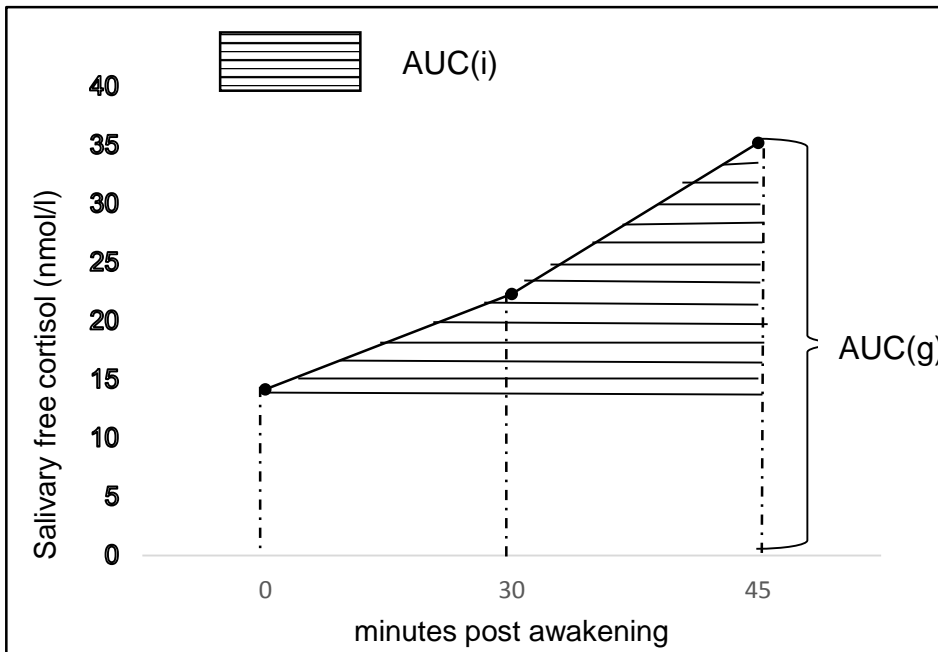


Figure 3.8 Representation of the area under the curve with respect to increase [AUC(i)] and the area under the curve with respect to ground [AUC(g)].

3.4.2 Ambulatory monitoring

The five electrocardiogram leads were attached using Ambu Blue VLC long term monitoring electrodes (Ambu Ltd, St Ives, UK) at the following locations: left anterior axillary line, intercostals space 5 (x2), sternum, manubrium sterni, right anterior axillary line, intercostals space 5. A real time test of the electrocardiogram signal was performed and the device was manually prompted to perform a blood pressure measurement before the device was programmed to automatically obtain readings of diastolic and systolic blood pressure at 30 minute intervals. The Actiheart was also attached using Ambu Blue VLC long term monitoring electrodes (Ambu Ltd, St Ives, UK). The electrode connected to the main body of the device was attached at V1 or V2, with the second electrode being attached 10cm away, on the left side of the body at approximately V4 or V5 (Figure 2.3).

3.4.3 Signal contingent experience sampling method.

Using a signal contingent experience sampling methodology the participant completed the positive and negative effect schedule and the modified workload questionnaire four times throughout the working day. These were subdivided into two blocks of equal duration (09:00 -13.00hs and 13:00 -17:00hs) with two prompts occurring within each 4 hour period. The signal took the form of alarms which were pre-programmed into the participant's smart phone. All subjective assessments were provided on paper, and the questionnaires were digitally scanned to email at the end of the working day.

3.4.4 Assessment of awakening and sampling times

The Medication Event Monitoring System is automatically configured to ignore any openings that occur within 15 minutes of the previous opening. Therefore, in order to configure the device to capture all openings, the default 15 minute filter in Powerview version 3.5.1 (Aardex, Switzerland) was deactivated prior to use. A new patient record was created in Powerview and 3 daily events were entered as the recording frequency, but no timings were stipulated, as timings were relative to time of awakening rather than clock time. Following completion of the case study all data was downloaded to Powerview. All opening times were identified and times entered into an Excel spreadsheet.

3.4.5 Experimental Protocols

Study one: Participants attended a familiarisation session at the laboratory where all equipment was demonstrated and the study protocol was explained verbally, with participants having the opportunity to ask questions about their participation in the study. Once informed consent had been obtained the participants were

asked to select two working days on which to undergo data collection. The days were required to be non-consecutive and to be expected to contain different levels of acute work-related demand, with the participants indicating the anticipated respective demand of the days. The participants were then provided with six pre-labelled Salivette collection systems. All labels detailed the sampling date, whether the sample was the awakening or post awakening sample, and had a space to indicate the time the sample was obtained. Additionally the label on the Salivette to be used for the awakening sample had a space to record the time of awakening. The participants were also provided with all questionnaires to complete in their own time and return on the first day of data collection. On the data collection days the participants were required to collect two saliva samples over the awakening period which were brought with them to the laboratory and stored at -20°C. Participants were then instrumented with the combined ambulatory electrocardiogram and blood pressure monitoring device (Cardiotens, Meditech, Budapest, Hungary) as well as the Actiheart. The participant's skin was prepared for the attachment of all electrodes by cleaning and vigorously abrading the relevant sites with a rough cloth to remove the stratum corneum. Five electrocardiogram leads were then attached using Ambu Blue VLC long term monitoring electrodes (Ambu Ltd, St Ives, UK) at the following locations: left anterior axillary line, intercostal space 5 (x2), sternum, manubrium sterni, right anterior axillary line, intercostal space 5. A real time test of signal integrity was performed and where the signal was not of sufficient quality the electrodes were repositioned and the signal test was performed again until a clear signal was received. The appropriate sized blood pressure cuff was then attached to the participant's non-dominant arm and a manual reading was conducted to ensure

the integrity of the cuff. The device was programmed to automatically obtain blood pressure readings at 30 minute intervals. Participants were advised that during a blood pressure reading they should hold their arm approximately level with their chest and refrain from movement as far as possible. The Actiheart was also attached using Ambu Blue VLC long term monitoring electrodes (Ambu Ltd, St Ives, UK) and a signal check was performed for 3 minutes, during which time the participant moved around freely. Figure 3.9 shows a fully instrumented participant.

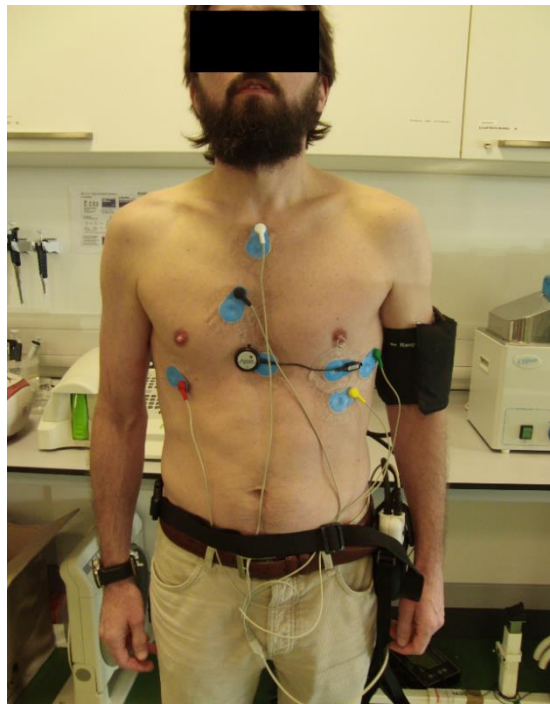


Figure 3.9 Participant equipped with both the Cardiotens and Actiheart monitors.

Upon the presence of an acceptable signal the monitor was set to short term record and re-attached to the electrodes. Prior to a leaving the laboratory the participants were advised that should the blood pressure cuff become, loose, uncomfortable, or inflate and deflate repeatedly during a reading, the cuff may need to be adjusted and to contact the researcher immediately. Otherwise the

participants were instructed to go about their working day as normal. At the end of the working day the participants returned to the laboratory to have the instrumentation removed. At this stage the participants placed a mark on the visual analogue scale to indicate how demanding their working day. Once the participants had left the laboratory, all data was downloaded and saved.

Study two: Assessments were performed on a total of 21 days: 3 separate blocks of seven consecutive days, giving 15 week days and 6 weekend days. All data collection occurred in the months of April and May. The variation in the nature of the participant's weekdays enabled further differentiation according to the nature of the assessment day. The assessment days were therefore categorised according to the following criteria: work day = day of contractual employment; research day – predominantly study related; Weekend = Saturday or Sunday with no work being performed. Additionally, one of the weeks included in the assessment period was deliberately selected as it contained a novel naturalistic stressor; the participant competed in his first competitive mountain bike race at the weekend.

A signal contingent experience sampling methodology was used to capture momentary information about workload and affect. The participant was notified, via pre-programmed random alerts on his mobile phone, when it was time to complete questionnaires. Four alerts were provided daily: two during the first half of the day (09.00 – 13.00 hours) and two in the second half of the day (13.00 –

17.00 hours). Paper questionnaires were used as these allowed for discreet completion enabling the participant to complete them without any undue delay, as may not have been the case had the questionnaire been presented electronically on their phone. All questionnaires were electronically scanned and date and time stamped prior to leaving work at the end of the day.

Following the 24 hour recording period the Actiheart monitor was removed, the data downloaded and the monitor was recharged. At this point the second Actiheart monitor was immediately attached using a new pair of electrodes and, following a brief test of the signal integrity, set for short-term recording. This process was repeated at 22.00 hours for the duration of the study – a total of 20 times.

Prior to commencement of each study week, 21 Salivette swabs were placed in the MEMS Smart cap bottle, and Salivette tubes were labelled with the study day number and sample number. Upon awakening the participant was required to immediately open the smart bottle, remove the first swab, replace the cap on the smart bottle and place the swab under the tongue for 1 minute. This was repeated 30 minutes and 45 minutes post awakening. Only a single swab was removed from the bottle at each time point in order to ensure that all samples were accurately time stamped and the participant was required to remain in the supine position until all samples had been provided.

3.5 DATA PROCESSING AND STATISTICAL ANALYSES

3.5.1. Questionnaire-based data

The 35 questions of the Management Standards Indicator Tool were reduced to provide mean scores (1-5) for each of the seven dimensions of the management

standards, with lower scores representing greater risk exposure. To provide a single measure of occupational stress, a global score was calculated by averaging the scores across subcategories, which enabled categorisation by psychosocial strain exposure: high or low (median \pm 0.5 SD). The demands dimension of the management standards was also used to categorise employees as being high or low risk (median \pm 0.5 SD). Additionally, individual responses to all questions were entered in to the Health and Safety Management Standards analysis tool and compared with the Health and Safety Executive's benchmark data, which comes from 136 organisations, to provide a measure of risk for each dimension. Data were also compared with average values for the target industries which, in addition to Education, comprise financial intermediation, public administration & defence, and health and social work (Webster & Buckley, 2008). Individual Work Ability Index scores were manually calculated using the published scoring system and were categorised as follows: "poor" (2-27), "medium" (28-36), "good" (37-43), and "very good" (44-49) (Ilmarinen, 2007). Ratings of perceived daily demand were calculated from the visual analogue scale, with each mm representing 0.1, therefore demand ranged from 0 to 10, with lower scores representing a lower level of demand.

3.5.2 Statistical Analyses

All statistical tests were performed using SPSS version 20. The distribution of all data was tested using the Shapiro-Wilk test of normality. Where data was found to be normally distributed, parametric tests were performed with non-parametric tests being used in the absence of a Gaussian distribution. Therefore, within-

group analyses performed by means of both paired *t*-tests and Wilcoxon-signed-rank tests and independent *t*-tests and Wilcoxon-Mann-Whitney tests were used to conduct between group analyses. Pearson's correlations were used for normally distributed data and Spearman's for data that did not meet the assumption of normality. The magnitude of the correlations was interpreted using Cohen's (1998) conventions: small = .10, moderate = .30, large = .50. With a sample size of 20 and an alpha level of .05, bivariate correlations would have 75% power to detect a large effect, 37% power to detect a moderate effect and 11% power to detect a small effect. To achieve a power of 80%, a correlation coefficient of .53 would be required. Within-subject correlations were performed following the process outlined by Bland and Altman (1995) which essentially involves treating the subject as a categorical factor using dummy variables in order to identify the amount of variation accounted for by different sources i.e. within and between subjects.

CHAPTER 4. The cardiovascular and autonomic response to psychosocial hazard amongst higher education employees: the role of acute demand.

4.1. INTRODUCTION

The 'ivory towers' of academia have traditionally afforded relative sanctuary from exposure to occupational stress, primarily through high levels of autonomy and intellectual freedom. The role of the academic was once clearly delineated, with teaching and research constituting the majority of workload, whilst administration accounted for relatively little work time (Houston, Meyer & Paewai, 2006). However, in the UK, universities have been forced to prioritise fiscal performance following reductions in public funding in the wake of the Education Reform Act (1988). UK Government policy now dictates that universities must contribute to the economy (Lam, 2010) with research funding being largely dependent upon this contribution (Etkowitz *et al.*, 2000). As a result, despite no reduction in teaching or research responsibilities, academics must devote significantly more time to administrative work (Kinman & Jones, 2003; Tight, 2010) and are increasingly being tasked with securing research funding through entrepreneurial activities. Academia is therefore no longer immune from the sources of occupational stress associated with globalisation and market forces.

Recent reports of academics suffering from stress as a result of overload are ample, with work overload, task overload, and role overload, as well as the difficulty of balancing multiple roles and lack of role clarity, being commonly cited factors (Winter, Taylor, & Sarros, 2000; Gillespie *et al.*, 2001; Kinman & Jones, 2003; Barrett & Barrett, 2007; Devenport, 2008). Stress has been identified as a key predictor of academics' intent to move institution (Ryan, Healy, & Sullivan, 2012), and is also associated with intention of leaving the profession entirely

(Kinman & Jones, 2003). The deleterious effects of exposure to stress upon health, particularly the incidence of hypertension and cardiac disease, are widely known, and a study of UK academics found that one quarter had suffered from a stress related illness in the previous year (Kinman & Jones, 2003). Higher education employees have also been shown to be at greater risk of psychological illness than the general population (Winefield *et al.*, 2003); and UK lecturers report poorer than average levels of psychological wellbeing (Johnson *et al.*, 2005).

Although the exact mechanisms are still to be determined, the autonomic nervous system is a likely pathway linking exposure to psychosocial strain and disease (Thayer & Lane, 2007). Heart rate variability, an independent predictor of cardiovascular mortality and cardiac events (Tsuji *et al.*, 1996; Kikuya *et al.*, 2000), provides a non-invasive insight into the functioning of the autonomic nervous system, with spectral analysis providing a means of elucidating the sympathovagal balance. Low and high frequency parameters broadly represent the sympathetic and parasympathetic branches respectively, whilst the low-to-high frequency ratio reflects the balance between these two components (Pumprla *et al.*, 2002). Reduced vagal tone and chronic sympathetic dominance of the autonomic nervous system have been found to represent risk factors for cardiovascular disease (Liao 1997; Curtis & O'Keefe, 2002) and exposure to general psychosocial strain is associated with increased low-to-high frequency ratio and blood pressure (Hjortskov *et al.*, 2004; Collins, Karasek, & Costas, 2005; Lucini *et al.*, 2005; Lucini *et al.*, 2007). Furthermore, perceived chronic exposure to psychosocial work-related strain has repeatedly been associated with

increased sympathetic dominance of the autonomic nervous system (Van Amelsvoort *et al.*, 2000; Vrijkotte, Van Doornen, & De Gues, 2000; Loerbroks *et al.*, 2010) and increased ambulatory blood pressure (Van Egeren, 1992; Fauvel *et al.*, 2001; Brown, James, & Mills, 2006; Guimont *et al.*, 2006).

In the UK, The Health and Safety Executive, who act as the national independent watchdog for work-related health, safety and illness, currently advocate the use of a risk assessment approach to identify environments believed to invoke work stress, through the application of their management standards and associated indicator tool (Health and Safety Executive, 2005). The Indicator Tool is a 35-item self-report questionnaire which measures exposure to various dimensions of work design that, if not properly managed, are associated with poor health and well-being, lower productivity and increased sickness absence. Despite being firmly grounded in occupational stress theory, the overarching premise of this approach is appealing in its simplicity, in that minimising exposure to factors known to represent a risk for the experience of stress reduces the incidence of stress-related problems. A recent nationwide survey of UK higher education employees reported lower than average scores on all but one of the management standards (Kinman & Court, 2010).

To date no attempt has been made to investigate associations between exposure to psychosocial risk factors, as measured by the management standards tool, and physiological markers of the stress response. Similarly, few attempts have been made to investigate the physiological response to work-related stress

amongst higher education employees. The main aim of the present study was therefore to investigate whether exposure to psychosocial risk factors at work is associated with autonomic function in higher education employees. However, although rarely attended to during ambulatory workplace assessment, there is evidence that heart rate variability is affected by acute work-related factors such as computer work (Hjortskov *et al.*, 2004) and lecturing to a large group of students (Filaire *et al.*, 2010). Therefore, a further aim of the study was to investigate whether work-time ambulatory assessments of heart rate variability and blood pressure are influenced by acute demand. The three hypotheses of the study were: i) academics would report greater exposure to psychosocial hazard and would have higher work-time ambulatory blood pressure and sympathetic dominance of heart rate variability than general staff; ii) scores on the management standards indicator tool would be positively associated with physiological stress responses i.e. greater perceived exposure to psychosocial hazard will result in greater blood pressure and sympathetic dominance of the autonomic nervous system; and iii) blood pressure and measures of heart rate variability will differ according to the acute work-related demand of the measurement day.

4.2. METHODS

Details of recruitment methods are provided in section 3.2.1. Twenty participants (13 male, 7 female) volunteered to participate in the study. Given the observational nature of the study, a case-control approach was adopted whereby the case comprised academic employees (n=10, 5 male: 5 female) with general employees forming the control group (n=10, 8 male; 2 female). All academic staff

had teaching responsibilities and the job title of “lecturer” whilst general staff exclusively worked in a support capacity, as administrators or technicians. The academics had a mean age of 40.6 ± 8.7 yrs and non-academics a mean age of 32.7 ± 5.8 yrs.

Details of the experimental protocol are provided in section 2.4.5 and the general process of data analysis is outlined in section 2.5.3. Non-parametric tests were used in the absence of a Gaussian distribution. Within-group analyses performed by means of paired *t*-tests and Wilcoxon-signed-rank tests. Independent *t*-tests and Wilcoxon-Mann-Whitney tests were used to conduct between group analyses on acute demand, blood pressure and all measures of heart rate variability. Spearman’s rank-order correlations were performed on measures of blood pressure, heart rate variability, and each of the seven management standards.

4.3. RESULTS

Mean scores for the cohort as whole revealed varied levels of perceived exposure to psychosocial hazard for different dimensions of the management standards, according to the categorical scores provided by the UK Health and Safety Executive’s analysis tool. Scores for the dimensions of, Demand, Control, Management Support and Peer Support fell within the “excellent” category (being at, above or close to the 80th percentile), relationships and control were categorised as being “good”, whilst “role” received a “poor” score (below average but above the 20th percentile) (Table 4.1). There was a clear group effect however, with general staff reporting “excellent” scores for all 7 dimensions of the indicator tool, whilst the academic group only achieved “excellent” scores for the

Control and Peer Support. The academics also reported “poor” scores for both Management Support and Relationships, and fell in the “very poor” category (below the 20th percentile) for both Role and Change.

4.3.1 Questionnaire data

Table 4.1 A comparison of mean Management Standards scores with benchmark data by occupational groups

Dimension	Academics		General Staff		All Staff	
	Score	Cat	Score	Cat	Score	Cat
Demands (SD)	2.99 (0.89)	P	3.68 (0.72)	E*	3.33 (0.88)	E
Control (SD)	3.95 (.065)	E	4.00 (.080)	E	3.98 (0.23)	E
M.Support (SD)	3.46 (0.99)	P	4.06 (0.87)	E*	3.76 (0.98)	E
P. Support (SD)	3.95 (0.55)	E	3.93 (0.66)	E	3.94 (1.14)	E
R'ships (SD)	3.65 (1.23)	P	4.15 (1.00)	E*	3.90 (1.14)	G
Role (SD)	3.84 (0.87)	V. P	4.48 (0.61)	E*	4.16 (0.81)	P
Change (SD)	2.77 (0.97)	V. P	3.37 (1.03)	E*	3.07 (1.04)	G
Global (SD)	3.51 (0.98)	†	3.96 (0.85)	†	3.73 (0.95)	†

Cat = Category: derived from comparison with benchmark data from 136 organisations.

E= Excellent: at, above or close to the 80th percentile, G= Good: Better than average but not yet at, above or close to the 80th percentile. P= Poor: Below average but above 20th percentile. V.P= Very Poor: below the 20th percentile - Urgent action needed. † UK HSE do not provide categorisation of a global score. M.Supp: management support. * denotes categorical difference from the academic staff

In all cases the participants correctly anticipated the respective demands of the two study days, as all individual scores on the visual analogue scale were greater on the more demanding day than on the less demanding day. The difference between scores for the two study days was significant for the cohort as a whole

($t=-2.172$, $p=0.43$, $d= -.049$), but when categorised by group, this difference only remained significant in the academic groups (Table 4.2).

Table 4.2. Self-reported acute demand by occupation and self-reported chronic psychosocial demand.

Group	Less Demanding Day	More Demanding Day
All Staff	3.64 ± 1.97	4.93 ± 1.93*
Academics	3.27 ± 1.54	5.60 ± 2.56*
General Staff	3.72 ± 1.99	4.57 ± 1.22

* Significantly different from less demanding day ($p<0.05$)

4.3.2 Physiological data

The average duration of ambulatory recording was 421 ± 39 minutes and all mean blood pressure readings were within normal ambulatory ranges (Mancia *et al.*, 1995). Several measures of autonomic regulation varied significantly between the two study days for the entire cohort of employees: systolic blood pressure diastolic blood pressure ($t=-2.464$, $p=.023$, $d = 0.64$), heart rate ($t=-2.873$, $p=.010$, $d = -0.82$), normalised low frequency power ($t=-3.680$, $p=.002$, $d = -.082$), normalised high frequency power ($t= 3.538$, $p=.002$, $d=0.80$) and low-to-high frequency ratio (Table 4.3). When categorised by job type, these same measures, with the exception of systolic blood pressure, remained significant in the academic group only.

Table 4.3. Ambulatory data according to acute demand presented by occupational group

	Academics		General Staff		All Staff	
	Less Demanding	More Demanding	Less Demanding	More Demanding	Less Demanding	More Demanding
SBP	120.72 ± 7.67	125.08 ± 5.59	122.52 ± 6.28	127.6 ± 9.55	121.62 ± 6.89	126.4 ± 7.73*
DBP	75.18 ± 5.85	77.95 ± 5.63*	76.48 ± 4.62	79.25 ± 4.51	75.83 ± 5.18	78.60 ± 5.0*
HR	76.94 ± 10.61	84.81 ± 13.58*	67.24 ± 6.67	68.34 ± 6.47	72.09 ± 9.96	76.58 ± 13.4*
LF	1497.9 ± 674.0	1857.5 ± 1150.0	2069.2±1078.6	2096.8±1036.3	1783.5 ± 23.1	1977.1 ± 72.5
LF(nu)	74.80 ± 13.85	81.5 ± 10.15*	74.0 ± 9.98	77.5 ± 7.28	74.4 ± 11.76	79.50 ± 8.8*
HF	558.50 ± 620.2	457.3 ± 489.1	757.0 ± 807.4	586.0±333.7	657.7 ± 708.1	521.6 ± 412.8
HF(nu)	24.10 ± 12.99	18.10 ± 9.10*	24.6 ± 9.43	21.60 ± 6.8	24.3±11.05	19.85±8.0*
LF/HF	4.15 ± 2.32	5.45 ± 2.66*	3.6 ± 1.89	4.0±1.78	3.87 ± 2.08	4.72 ± 2.33*

* Significantly different from less demanding day ($p < 0.05$). SBP: systolic blood pressure, DBP: diastolic blood pressure, HR: heart rate, LF: low frequency power, LF(nu): low frequency power in normalized units, HF: high frequency power, HF(nu): high frequency power in normalized units, LF/HF: low to high frequency ratio.

4.3.3 Relationship between questionnaire data and physiological data.

Table 4.4 shows associations between all dimension of the Health and Safety Executive's indicator tool and parameters of heart rate variability. "Demand" demonstrated a moderate to strong negative association with the low-to-high frequency ratio on both days ($r = -.485$, $p < .03$ and $r = -.583$, $p < .01$) for the less and more demanding days respectively. The "relationships" standard demonstrated a moderate negative association with the low-to-high frequency ratio on the more demanding day ($r = -.466$, $p < .04$).

Table 4.4. Correlations between HSEMS and Heart Rate Variability

Time		LFnu			HFnu			LFHF		
		LD	MD	Δ	LD	MD	Δ	LD	MD	Δ
Global	r	-.052	-1.57	-1.24	.046	.176	.162	-.268	-.353	-.286
	p	.827	.510	.602	.847	.522	.906	.253	.114	.627
Demands	r	-.246	-.415	-.086	.251	.411	.108	-.485*	-.583*	-.510
	p	.257	.069	.717	.286	.109	.579	.030	.007	.431
Control	r	-.147	.032	-.233	.150	.049	.213	-.275	-.113	.061
	p	.536	.892	.323	.527	.874	.265	.241	.624	.291
Man'	r	.040	-.076	-.185	-.030	.036	.089	-.104	-.248	-.269
	p	.867	.749	.435	.854	.702	.470	.553	.214	.425
Peer	r	-.019	-.046	-.030	.036	.089	.057	-.104	-.248	-.269
	p	.938	.848	.900	.879	.770	.865	.661	.499	.457
R'ships	r	-.108	-.260	-.165	.106	.269	.180	-.335	-.466*	-.454
	p	.650	.269	.486	.656	.317	.976	.149	.038	.295
Role	r	-.045	-.103	-.063	.024	.117	.120	-.177	-.089	.015
	p	.852	.664	.792	.920	.631	.708	.456	.386	.692
Change	r	-.356	.274	-.285	-.535	-.250	-.311	-.281	-.152	-.010
	p	.123	.242	.223	.127	.284	.162	.203	.557	.729

*Significant at $p < 0.05$, ** significant at $P < 0.01$. LD = Less Demanding Day. MD = More Demanding Day. Δ = Change from LD to MD.

4.4. DISCUSSION

The aim of the present study was to investigate exposure to psychosocial hazard in higher education employees and the physiological consequences of this exposure. It was hypothesised that: i) academics would be exposed to greater psychosocial hazard and would demonstrate higher work-time ambulatory blood pressure and greater sympathetic dominance of heart rate variability than general staff; ii) management standards indicator tool scores would be associated with autonomic functioning; and iii) the physiological response to work would be influenced by changes in acute work-related demand. The study found that academics reported poorer scores than the general staff, but this was not reflected in work-time physiological functioning, as no differences were found in either blood pressure or heart rate variability between occupational groups. Therefore, the findings do not completely support the first hypothesis. However, as sympathovagal balance was associated with chronic exposure to both high levels of demand and poor relationships, the second hypothesis is supported. Additionally, daily work-related demands were shown to influence work-time ambulatory heart rate variability and blood pressure, at least amongst academics, which supports the third hypothesis of the study.

This appears to be the first study to report upon the disparity in perceived exposure to psychosocial hazard according to role type amongst higher education employees, using the Indicator Tool. The unfavourable scores reported by the academics for all dimensions of the management standards, with the exception of control and peer support, suggests that this group of employees may

be subjected to potentially harmful levels of work-related psychosocial risk factors. The dimension of Role received a particularly poor score, lending weight to the contention that academics are now expected to balance multiple roles and supporting previous findings regarding role as a source of stress amongst academics (Winter, Taylor & Sarros, 2000; Gillespie *et al.*, 2001; Kinman & Jones, 2003; Barrett & Barrett, 2007; Devenport, 2008). The “excellent” level of Control reported by both occupational groups is arguably indicative of the high level of autonomy that has historically been considered to characterise academic work, suggesting this favourable aspect of the job remains prominent, and also appears to extend to non-academic roles, possibly as a result of the institutional culture. Certainly, high levels of control have previously been reported amongst academics (Winter Taylor & Sarros, 2000; Winefield & Jarrett, 2001). Equally, the “excellent” level of Peer Support reported by academics and general staff alike may reflect the collegiate culture of academic institutions.

Despite reporting different levels of exposure to psychosocial hazard, academic and general staff did not differ in terms of their physiological response to work on either day. There are a number of possible explanations for this, the most simplistic being that different exposures to psychosocial hazard, as quantified by the Indicator Tool, do not significantly influence work-time autonomic functioning. An alternative explanation is that there may be a discrepancy between actual, or perceived, and reported psychosocial hazard, with academics reporting inflated exposures. However, neither of these explanations satisfactorily accommodates previous claims that the Indicator Tool has been associated with stress (Gyllensten & Palmer, 2005; Bevan, Houdmont and Menear, 2010) and stress

related health outcomes (Kerr, McHugh & McCrory, 2009). A final explanation, provided by the inter-individuality of the physiology underlying the stress response, may therefore be more plausible. It has previously been demonstrated that measures of heart rate variability can differ substantially between individuals (Thayer & Lane, 2007) and the present study certainly supports this inter-individuality in autonomic function. Additionally, Ilies *et al.* (2010) recently reported that a between-individuals analysis failed to find an association between workload and blood pressure, whilst the within-individual approach revealed positive associations between the two variables. Therefore, traditional cross-sectional analysis may not provide the optimal means of investigating the physiological response to work-related psychosocial hazard unless consideration is given to individual baseline values. However, this raises its own methodological challenges and it has yet to be established whether reactivity to acute laboratory stressors bears any correlation to reactivity during exposure to chronic, naturally occurring, stressors (Ho *et al.*, 2010).

Notwithstanding the somewhat rudimentary method of quantifying the acute demand of the two study days in relative terms, the present study demonstrated that perceived levels of daily work-related demand influence the physiological response to work amongst academics. In the absence of clinical guidelines, it is not possible to quantify the extent to which the increase in the low-to-high frequency ratio in response to greater acute work-related demand represents a risk factor. However, as the change in sympathovagal balance was predominantly effected by a reduction in vagal tone, which has been shown to be an independent predictor of ill-health and mortality (Singh *et al.*, 1998; Thayer,

Yamamoto, & Brosschot, 2010; Huikuri & Stein, 2012), it seems sensible to attempt to minimize the extent to which the work environment elicits such a response.

Irrespective of potential long-term consequences, the variation in physiological function in response to acute demand is an important finding with significant methodological implications for future research. Such a finding suggests that in order to meaningfully interpret ambulatory physiological data, during work time at least, consideration must be given to the acute characteristics of the assessment day and how representative they are of the norm. Whilst this may seem somewhat obvious, given the main purpose of ambulatory monitoring is to obtain an assessment within the environment of interest, workplace investigations seldom attempt to quantify the acute psychosocial characteristics of the environment, beyond that which is typical to the specific occupation. However, there is a growing acknowledgement of the dynamic nature of the work environment (Ilies & Judge, 2002; Ilies & Judge 2004; Beal & Weiss, 2003; Ilies, Dimotakis, & De Pater, 2010) which should not be overlooked for the sake of simplicity, and assessments should therefore be conducted on multiple work days of varying demand. Additionally, adopting such an approach would simultaneously go some way to addressing the issue of inter-individuality by enabling analysis to be performed at the within-individual level. Differences in individual physiological response across days of varying demand may potentially provide a more meaningful insight into the extent to which employees are coping with the demands of work than attempting to incorporate baseline values obtained in the laboratory.

As autonomic function only varied in response to acute daily demand amongst academics and not general staff, it is tempting to surmise that this reflects differences in the nature of the roles. Whilst this may well be the case, a related explanation may be that academics were better able to predict the characteristics of the study days in advance and therefore the assessments were performed on more divergent days than amongst the general staff. However, as the academic group reported higher levels of exposure to psychosocial risk factors, including work-related demand, than the general staff, it could equally be the case that acute demand is superimposed against chronic demand, with the cumulative effect driving the autonomic response. This could have potentially significant implications for work design, as it may be that employees reporting lower exposure to chronic psychosocial hazard are better able to cope with sporadic exposure to elevated demands and, conversely, employees who experience a higher basal level of demand should not be exposed to acute episodes of higher than average demand. The possible interaction between chronic and acute exposure to psychosocial demand certainly lends further weight to the argument that the single-shot approach to investigating the autonomic and cardiovascular response to the psychosocial work environment is limited by its inability to account for the dynamism that is inherent in many occupations. Further investigations should attempt to more accurately establish the mechanisms accounting for the apparent influence of job type upon the physiological response to changes in acute demand.

According to the conceptual basis of the management standards, the dimensions which obtain the lowest categorical score could be considered to represent the

greatest threat to employee health and wellbeing. However, although the academics reported “very poor” scores for both Role and Change, the present study failed to detect an association between these dimensions and physiological functioning, suggesting that if these dimensions do influence health it is not via autonomic mechanisms. On the other hand, both Demand and Relationships were associated with enhanced sympathetic dominance of the nervous system, despite being categorised as merely being “poor”. The Demand dimension of the Indicator Tool has previously been shown to be a significant predictor of the subjective experience of stress (Gyllensten & Palmer, 2005) and the present findings offer support for exposure to demand being implicated in the relationship between workplace strain and stress related ill-health. This may have potential implications for the interpretation of the management standards indicator tool or for prioritising workplace interventions, which has been identified as a consideration where respondents report poor scores across several dimensions of the Indicator Tool (Bevan, Houdmont and Menear, 2010).

Limitations

In addition to the relatively small sample size, the possibility of self-selection bias cannot be ruled out. Although the study was designed to be as minimally invasive as possible, employees exposed to very high levels of psychosocial work-related hazard may be less likely to participate in research which places additional demands upon them during the working day. Additionally, as the participants selected the study days, it is reasonable to assume they may have deliberately precluded participation on days they anticipated being unusually high in acute

demands, given the time required to have the instrumentation attached and removed. Certainly, variation in the acute demands of the two study days was relatively small, so the full extent of variation in autonomic function in response to acute demands may not have been captured by the present study.

Contribution of the present results to the thesis.

- Further evidence that academics have greater exposure to psychosocial hazard, and poorer workability, than non-academic higher education employees.
- Academics and general higher education employees did not demonstrate differences in sympathovagal balance over the working day.
- Academics, but not general staff, demonstrate significant variation in sympathovagal balance in response to an increase in acute work-related demand
- Chronic exposure to work-related demand was associated with greater sympathetic dominance of the autonomic nervous system.
- The use of a simple visual analogue scale to obtain a subjective assessment of the acute demands of a working day appears a valid means of quantifying acute work-related demand.

CHAPTER 5. Variation in the cortisol awakening response in higher education employees according to acute and chronic work-related factors.

5.1 INTRODUCTION

The cortisol awakening response is widely used physiological marker of work related strain (Preussner *et al.*, 2003; Kunz-Ebrecht *et al.*, 2004b; Schlotz *et al.*, 2004; Alderling *et al.*, 2006; Eller *et al.*, 2006; Thorn *et al.*, 2006; Maina *et al.*, 2009a; Maina *et al.*, 2009b; Mikolajczak *et al.*, 2009) yet no attempt has been made to investigate the response in the relation to either the Work Ability Index (Ilmarinen, 2007) or the Management Standards (Health and Safety Executive, 2007).

A relatively widely used means of investigating the effects of the work environment upon the cortisol awakening response work is to directly compare samples obtained on work and non-work days. Kunz-Ebrecht *et al.* (2004b), Schlotz *et al.* (2004), Thorn *et al.* (2006), Liberzon *et al.* (2008) and Maina *et al.* (2009a) all identified differences in the awakening response of cortisol on work-day and weekend days. Despite this evidence pointing to the involvement of state characteristics upon the cortisol awakening response, the potential for variation in acute work-related characteristics is seldom attended to. Assessments are generally performed on a single working day (Kunz-Ebrecht, 2004a; Alderling *et al.*, 2006; Eller *et al.*, 2006), or values are aggregated across multiple days to obtain an average value for each individual (Wust *et al.*, 2000).

In one of the few studies to investigate the cortisol awakening response across multiple work days, Schlotz *et al.* (2004) sampled the cortisol awakening

response in 160 participants on six consecutive days and found the response to be stable. However, as no assessment of daily psychosocial characteristics was undertaken (predicted or actual) and 36% of the participants were either unemployed or retired, it is possible that the weekdays did not differ from each other in levels of anticipatory demand. More recently, Liberzon *et al.* (2008) found that variation in the acute characteristics of work altered the cortisol awakening response among a cohort of sailors; there was a more pronounced response when at sea compared to being onshore. Whether variation in acute work characteristics within a more stable working environment elicits similar differences is unclear.

There is also a growing body of evidence to suggest that the cortisol awakening response demonstrates substantial within-person variability (Kirschbaum & Hellhammer, 1999; Stone *et al.*, 2001; Hruschka *et al.*, 2005; Adam *et al.*, 2006; Dahlgren *et al.*, 2009; Stalder *et al.*, 2009; Stalder *et al.*, 2010). Recently, Ross *et al.* (2014) have suggested that future research should focus upon short-term fluctuations in stress, the cortisol awakening response and health, rather than attending to average values for an individual. Therefore the present study will also give consideration to the acute work-related characteristics of the assessment day.

In summary, the aim of the present study was to investigate whether the cortisol awakening response is associated with either the Management Standards Indicator Tool or the Work Ability Index within a cohort of higher education

employees, and whether variation in the anticipated demand of work days influences the cortisol awakening response. It was hypothesised that that the response would differ according to i) job type (academic v non-academic), ii) type of day (work v weekend) and, iii) relative anticipated demand (more v less demanding work day). Additionally, it was hypothesised that, iv), the cortisol awakening response would be associated with self-reported exposure to psychosocial hazard as measured by the Health and Safety Executive's Management Standards Indicator Tool

5.2 METHODS

Details of recruitment are provided in section 3.2.1 and details of participants is provided in section 4.2.1. Statistical analyses were initially performed using aggregated work day values and subsequently both work days were considered individually. Although all samples were included in the biological analysis, where participants failed to provide a complete set of saliva samples, or reported at least one negative awakening response, i.e. the volume of salivary free cortisol in second sample did not exceed the first by at least 2.5 nmol/l (Wust *et al.*, 2005) those participant's results were excluded from statistical analysis to reduce the potential effect of inter-individual variation. A one way repeated measures analysis of variance (ANOVA) was performed to investigate whether the time of awakening differed between study days, with minutes transformed to percentages of an hour. A repeated measures ANOVA was performed to test for the effects of sampling time and day with two within persons factors: day (less demanding work day/more demanding work day/weekend) and time of day

(awakening and 30 minutes post-awakening). To test for differences in the release of salivary free cortisol over the awakening period according to occupation type, three-way mixed ANOVAs were performed with day and sampling time as within subject factors and occupation type as the between subject factors. Where the main effect revealed significant differences, pairwise Bonferroni corrected comparisons were performed, with a Greenhouse-Geisser correction applied where Mauchley's test revealed the data violated the assumption of sphericity ($p < 0.05$). Bivariate correlations were performed to investigate the relationship between questionnaire responses and measures of salivary free cortisol.

5.3. RESULTS

Awakening and sampling times are shown in Table 5.1. No differences were found in awakening time across the 3 study days ($p > 0.05$).

Table 5.1. Mean self-reported salivary cortisol sampling times by day

Day	Sample 1	Sample 2
Less Demanding	07:08 ± 34	07:49 ± 33
More Demanding	07:04 ± 32	07:33 ± 32
Weekend	07:28 ± 31	07:58 ± 24

Time in hours and minutes ± SD in minutes, sample 1: awakening sample, sample 2: 30 minutes post-awakening.

Timing-related compliance was defined as there being a delay of less than 10 minutes between reported time of awakening and initial sample, and the second sample being provided no more than 40 minutes after awakening. No incidents

of non-compliance were reported. However, five participants provided at least one non-adherent sample; either as a result of failing to provide a full complement of samples, providing at least one dry sample, or not demonstrating an awakening response. This level of adherence is not unusual; previous studies have reported levels of non-compliance ranging from between 14 to 44% (Wust *et al.*, 2001; Maina *et al.*, 2009; Karlson *et al.*, 2010; Smyth *et al.*, 2013). Samples from the remaining 15 participants were included in the statistical analysis.

Mean values of salivary cortisol increased significantly from (12.93 ± 5.48 nmol/l) at awakening to (20.25 ± 7.76 nmol/l) at 30 minutes post awakening. The effect of sample time was found to be significant ($F [1, 14] = 30.07, p < .001$; partial eta squared = .682) providing evidence for the existence of the anticipated cortisol awakening response (Figure 5.1).

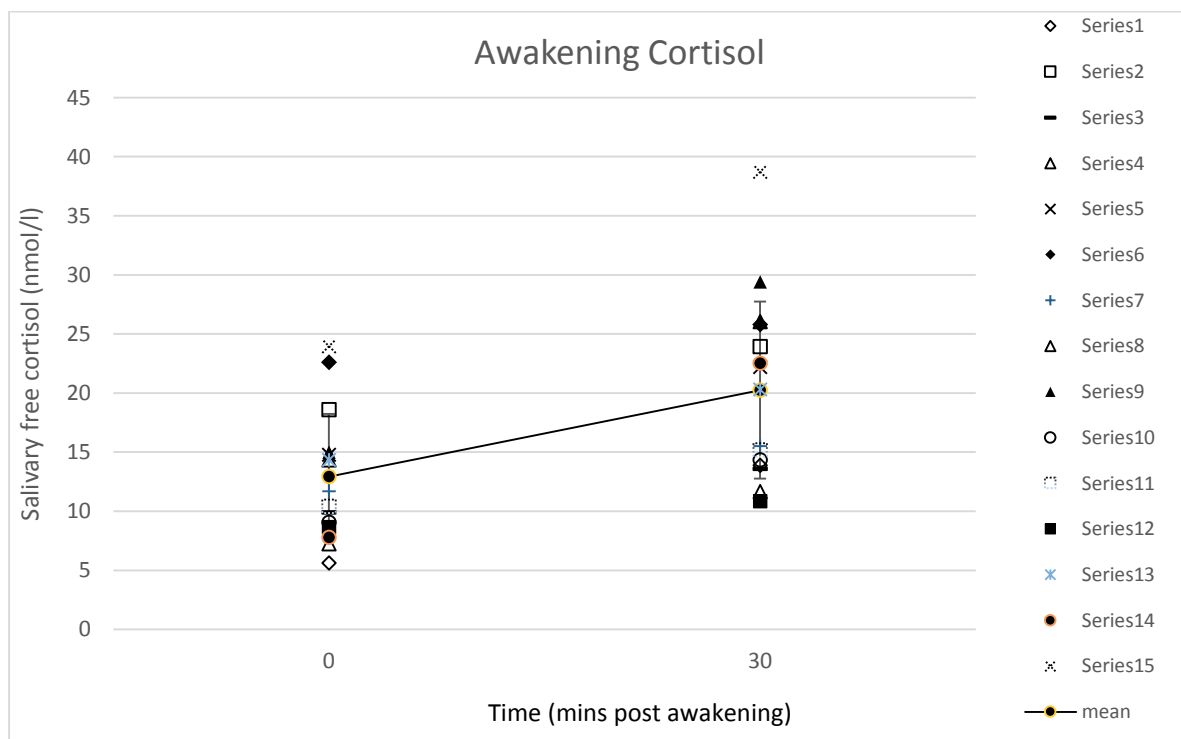


Figure 5.1. Mean values for salivary free cortisol by sample time.

The aggregated workday interaction effect of salivary free cortisol over the awakening period was significantly greater than the increase on the weekend day (8.82 ± 6.38 nmol/l versus 4.71 ± 4.37 nmol/l) (Figure 5.2).

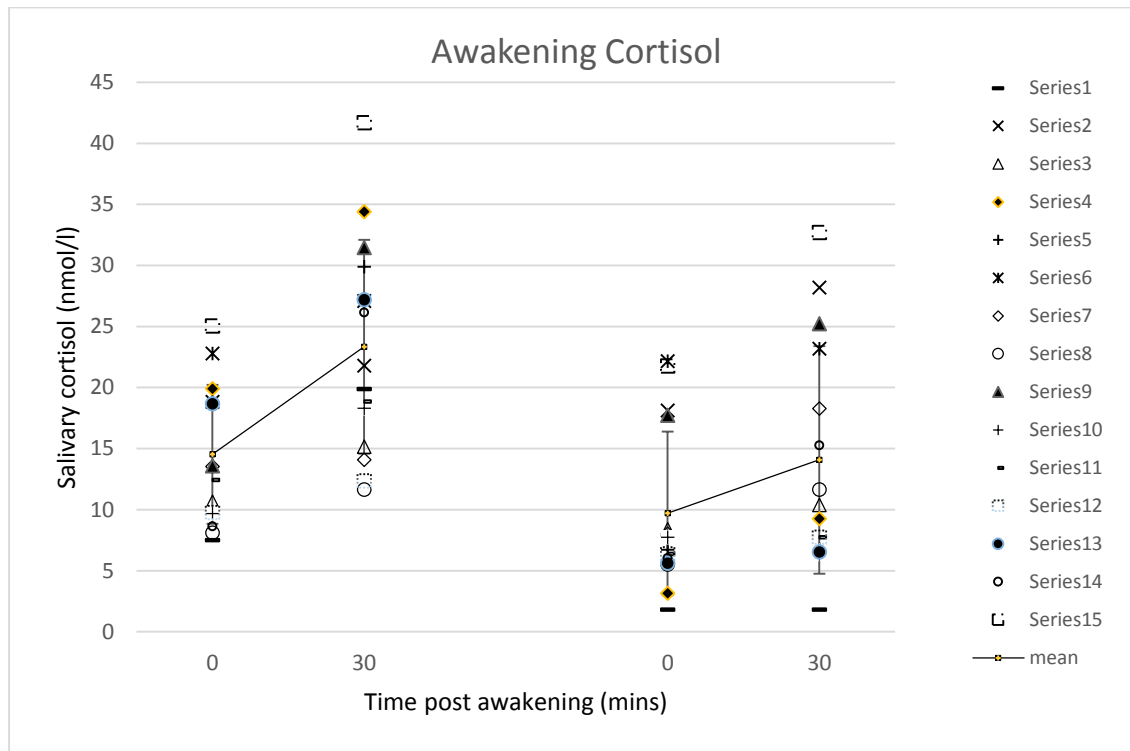


Figure 5.2. Average workday and weekend awakening cortisol response. Wake: awakening sample, 30:30 minutes post awakening.

An awakening response was observed on all three study days with salivary free cortisol being greater 30 minutes post awakening than on awakening (Figure 5.3). The response was found to differ according to the type of day ($F [2, 28] = 6.95$, $p < 0.01$; partial eta squared = .332). Pairwise comparisons revealed the awakening response to be greater on the “more demanding” day than the “less demanding” day, or the weekend ($p < .05$). However, there was no difference between the less demanding work day and the weekend ($p > .05$).

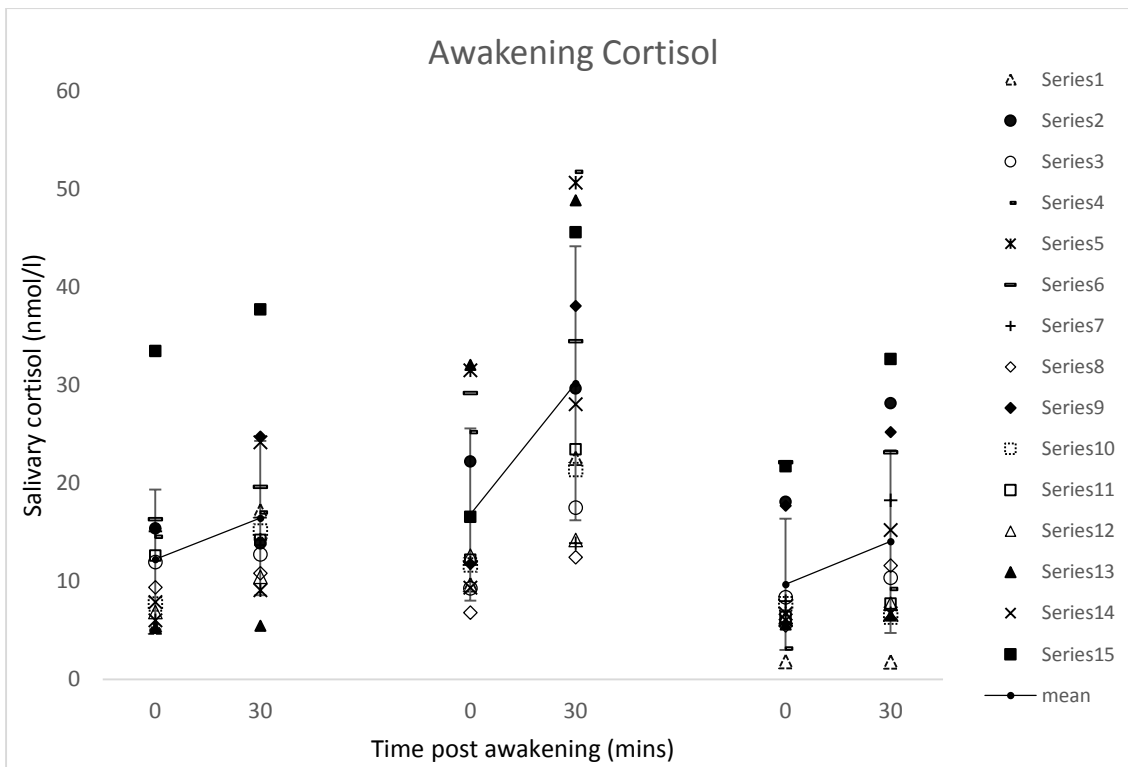


Figure 5.3. Awakening cortisol response by day. Wake: awakening sample, 30: 30 minutes post awakening

Mean levels of salivary free cortisol in the academic group increased from 13.03 ± 7.89 nmol/l to 21.49 ± 14.15 nmol/l over the awakening period whilst the non-academic group showed an increase from 11.91 ± 7.61 to 20.37 ± 10.88 . There was no difference in the mean cortisol awakening response according to job type ($F [1, 13] = .106, p > .05, \text{partial eta squared} = 0.0$) (Figure 5.4).

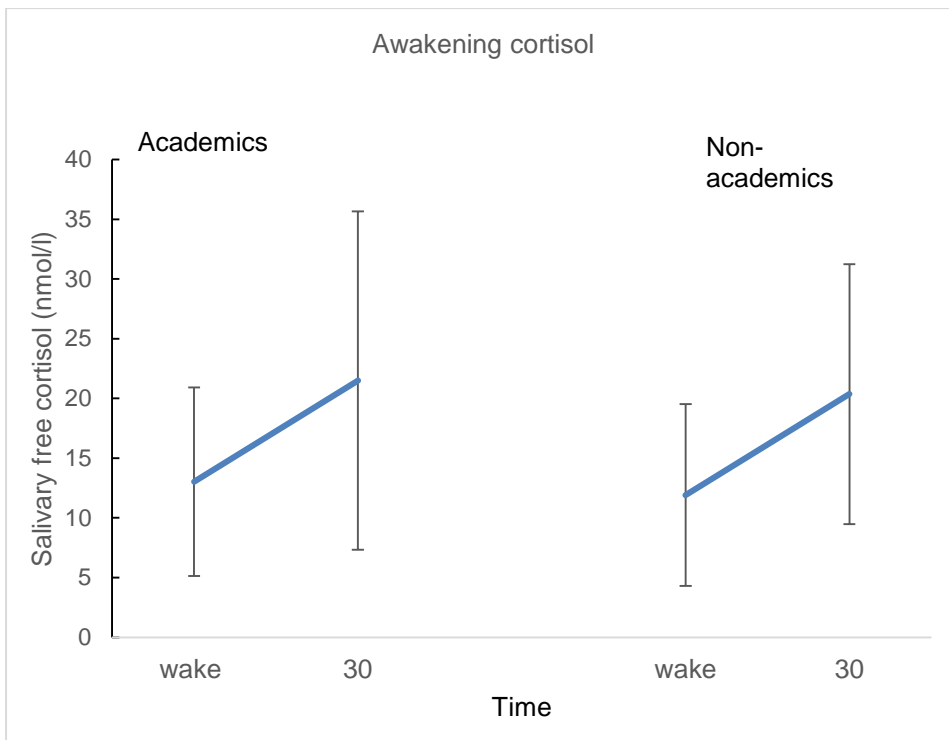


Figure 5.4. Awakening cortisol response according to occupation. Wake: awakening sample, 30: 30 minutes post awakening

No associations existed between the Work Ability Index and the cortisol awakening response on any day (Table 5.2). Similarly there were no associations between awakening cortisol and any of the seven dimensions of the Health and Safety Executive’s Management Standards Indicator Tool.

Table 5.2. Associations between questionnaire data and awakening saliva cortisol

	Less Demanding			More Demanding			Weekend		
	0	30	Inc	0	30	Inc	0	30	Inc
Demand	-.105	-.045	.125	-.446	-.293	-.247	.120	.183	.252
(p value)	.710	.873	.658	.249	.107	.374	.670	.513	.365
Control	-.342	-.218	.135	-.318	-.433	.342	.004	-.085	-.079
(p value)	.212	.435	.631	.249	.107	.212	.990	.764	.779
M.Supp	-.203	-.179	.025	-.022	.204	.061	-.201	.219	.316
(p value)	.461	.523	.929	.939	.467	.829	.473	.433	.252
P.Supp	-.353	-.254	.127	-.446	-.211	.237	-.237	.160	.276
(p value)	.197	.361	.652	.095	.449	.395	.394	.569	.319
R'ships	-.196	-.023	.258	-.436	-.094	-.004	.112	.188	.031
(p value)	.483	.934	.354	.104	.740	.990	.692	.503	.914
Role	-.185	.143	.339	-.393	-.114	.165	-.048	.041	.141
(p value)	.509	.610	.216	.148	.687	.556	.865	.885	.617
Change	-.361	-.094	.236	-.350	-.185	.079	-.411	-.039	-.019
(p value)	.187	.740	.397	.201	.509	.779	.128	.891	.947
WAI	-.074	.205	.418	-.363	-.069	-.158	.110	-.099	-.140
(p value)	.794	.464	.121	.425	.480	.574	.565	.959	.618

LD: less demanding, MD: more demanding, WE: weekend, 0: awakening sample, 30: 30 minutes post awakening sample, inc: increase over awakening period, i.e. 30-0. M.Supp: Management Support, P.Supp: Peer support, R'Ships: relationships. WAI: Work Ability Index.

5.4 DISCUSSION

The present study was performed to investigate the cortisol awakening response in a cohort of higher education employees. It was hypothesised that the response would differ according to: i) job type (academic v non-academic), ii) type of day (work v weekend) and, iii) relative anticipated demand (more demanding v less demanding day). Additionally, it was hypothesised that, iv), the cortisol awakening response would be associated with self-reported exposure to psychosocial hazard as measured by the Health and Safety Executive's management standards indicator tool. The results provide further support for the existence of a marked increase in salivary cortisol in the period immediately following awakening in healthy adults, and levels of salivary free cortisol were within the normal range for healthy adults (Clow *et al.*, 2004). However, as type of job had no effect upon the response, the results do not support the first hypothesis. There is, however, partial support provided for the second hypothesis, as the awakening response differed between the weekend and the "more demanding" working day. Additionally, as the response on the "more demanding" workday was greater than on the "less demanding" workday, hypothesis iii is supported. There was no association between any of the seven individual dimensions of the management standards indicator tool and the cortisol awakening response on any assessment day leading to a rejection of hypothesis iv.

The expectation that the cortisol awakening response would differ according to job type was based upon two assumptions derived from the existing literature.

Firstly, academic staff experience higher levels of work strain than general higher education staff (Kinman & Court, 2010), and secondly; work strain is associated with the cortisol awakening response at the cross-sectional level (Steptoe *et al.*, 2000; Preussner *et al.*, 2003; Kunz-Ebrecht *et al.*, 2004; Schlotz *et al.*, 2004; Eller & Hansen, 2007; Maina *et al.*, 2009a; Maina *et al.*, 2009b). The results of the present study support the assertion that academics are exposed to greater psychosocial hazard, and poorer levels of workability, than the general staff, suggesting the first assumption was correct. However, as this did not translate to differences in the cortisol awakening response, both hypothesis ii and iv were essentially rejected for the same fundamental reason: work-related psychosocial factors were not related to salivary free cortisol release over the awakening period. There are a number of possible explanations as to why this may have been the case. Firstly, the issue of statistical power needs to be addressed; due to the small sample size the lack of statistical significance in the present study may have resulted from insufficient statistical power. In hindsight, the sample size should perhaps have been informed by a priori power analyses (Lenth *et al.*, 2001), although this is not without its own problems, being reliant upon a subjective interpretation of what constitutes a meaningful difference (Muller & Benignus, 1992).

Notwithstanding issues of statistical power, the lack of between group differences in the cortisol awakening response and the lack of association between psychosocial hazard and the cortisol awakening response, may reflect differences in within-individual characteristics. The transactional stress theory (Lazarus *et al.*, 1968) asserts that the presence of stress may be less of a concern

for an individual's wellbeing than the way in which that individual appraises and copes with stress. That is to say that a stress response only occurs when a particular person interacts with a particular type of environment. Furthermore, Bevan *et al.* (2010, p.192) assert that "psychosocial hazard exposure is not necessarily causally linked to stress-related outcomes; unlike many chemical, biological, and physical hazards, psychosocial hazard exposure does not by default lead to harm." This is partly accounted for by the fact that individuals may differentially perceive certain psychosocial work characteristics to represent either a threat or a challenge (Bevan *et al.*, 2010). Certainly, biopsychosocial analysis of challenge and threat motivation has shown that an individual's appraisal of a performance environment determines their physiological response (Blaskovich & Mendes, 2002). Additionally, trait characteristics including; hardiness, coping (Powel & Schlotz, 2012), optimism (Lai *et al.*, 2005) dispositional affect (Lai *et al.*, 2005) and trait anxiety (Therrien *et al.*, 2008) have been shown to be related to stress reactivity of the hypothalamic-pituitary-adrenal axis and the cortisol awakening response. Similarly, personality and temperament may affect an individual's sensitivity to stressors and their threshold for physiological arousal (Tyrka *et al.*, 2006). The hypothesis that differences in exposure to psychosocial hazard, according to role, assumes that the groups are similar in trait characteristics. Despite previous reports that the cortisol awakening response is associated with job strain (Preussner *et al.*, 2003; Kunz-Ebrecht *et al.*, 2004b; Schlotz *et al.*, 2004; Alderling *et al.*, 2006; Eller *et al.*, 2006; Thorn *et al.*, 2006; Maina *et al.*, 2009a; Maina *et al.*, 2009b; Mikolajczak *et al.*, 2009) the potential involvement of personal trait characteristics, and indeed non-work factors in the cortisol awakening response would appear important. As the

present study did not give any consideration to trait characteristics during participant selection the potential confounding effects of such within-subject differences cannot be ruled out.

A related explanation for the lack of association between work-related factors and the cortisol awakening response may lie in the questionnaire based assessment tools themselves. By focusing on environmental factors, the Health and Safety Executive's Management Standards Indicator Tool ignores the importance of the individual in the stress process. This is potentially a limitation of the Management Standards approach; it was designed for use at an organisational level to minimise risk (Cousins *et al.*, 2004), but this method fails to attend to differences in individual employee's characteristics, perception and resources. Therefore, individual scores may provide very little information regarding the extent to which the environment is a cause for concern for that individual. Although the risk assessment approach that informs the Health and Safety Executive's Management Standards appears theoretically sound, in practice it may not always be possible to prevent employees being exposed to higher levels of psychosocial hazard. Therefore, the extent to which an individual can cope with a certain level of exposure remains an important issue. This highlights the problem of relying on a questionnaire based assessment of work strain. Not only must attention be given to the work environment, but also to the individual's perception of the environment and their individual trait characteristics. Even then the conclusions that can be drawn from questionnaire data with regards the physiological consequences of work for a particular individual rely upon some degree of generalisation. Additionally, although the Health and Safety Executive

claim that exposure to psychosocial hazard is associated with poor health and well-being (Health and Safety Executive, 2007), there is currently a lack of empirical evidence investigating the physiological consequences of psychosocial hazard assessed using the indicator tool (Health and Safety Executive, 2005). The present findings do not offer any support for the Management Standards Indicator Tool being associated with functioning of the hypothalamic-pituitary-adrenal axis amongst higher education employees.

Turning to the Work Ability Index, academics and non-academics were categorised as having “good” and “very good” workability respectively. This is not particularly surprising given that having a non-strenuous job is one of the most significant factors for retaining workability (Lindberg *et al.*, 2005). However, according to the scoring of the index the “good” category covers a range of scores between 37 and 43, whilst the “very good” category applies to scores between 44 and 49 (Morschhäuser and Sochert, 2006). Therefore, the non-academics mean Work Ability Index score actually fell between the two categories suggesting there was little real difference between groups. This could certainly account for the lack of between group differences in the cortisol awakening response.

Findings regarding variation in the cortisol response according to the acute characteristics of the assessment day are more encouraging. The fact that the aggregated workday awakening cortisol response was greater than the response which occurred on the weekend days is in accordance with much of the existing literature (Kunz-Ebrecht *et al.*, 2004; Schlotz *et al.*, 2004; Thorn *et al.*, 2006; Maina *et al.*, 2009; Mikolajczak *et al.*, 2009). This supports the contention that

work days are characterised by higher levels of anticipatory stress than non-work days which, according to the “anticipation hypothesis” (Powell & Schlotz, 2012), causes greater cortisol secretion, as the person prepares to meet the additional challenges to be faced in the day ahead (Fries *et al.*, 2009). The magnitude of the differences between workdays and weekend days was greater than that previously found in a cohort of call centre workers (Maina *et al.*, 2009), but similar to those demonstrated by a cohort of British civil servants (Kunz Ebrecht *et al.*, 2004). However, caution must be exercised when attempting to draw conclusions based upon comparisons between the absolute values reported previously and those in the present study without giving due consideration to the specific immunoassay kit employed in the analysis. A recent study investigating the levels of agreement between several widely available immunoassays, including the specific kit used in the present study, reported absolute salivary cortisol values to be ‘barely comparable’ between different commercial systems (Miller *et al.*, 2013). This is not to say that comparisons cannot be drawn between studies, but that the differences in patterns of cortisol secretion are perhaps more meaningful than the absolute levels of cortisol unless conversions are performed on all mean values. The present study revealed a sharper increase in cortisol release over the awakening period on weekdays compared with weekends, which is in accordance with previous reports that the dynamic rise is greater on workdays compared with weekend days (Kunz-Ebrecht *et al.*, 2004b; Thorn *et al.*, 2006).

In addition to confirming that the cortisol awakening response differs according to whether sampling occurs on a work day or a leisure day, the present study found the cortisol awakening response to be greater on the more demanding work day compared to the less demanding work day, and weekend days. Given that

the workplace has previously been shown to contain a high degree of day-to-day variation in demand (Butler, *et al.*, 2005; Totterdell *et al.*, 2006), workload (Sonnentag & Bayer, 2005; Ilies *et al.*, 2007; Ilies *et al.*, 2010) job satisfaction (Ilies & Judge, 2002) and mood (Miner *et al.*, 2005) these results are not particularly surprising. However, although Kamark *et al.* (2005) and Ilies *et al.* (2010) found cardiovascular activity to be vary according to daily work characteristics, no previous investigations have given consideration to whether the cortisol awakening response demonstrates similar variation. Therefore, the present findings represent a novel contribution to the literature.

The limitations of relying purely upon cross-sectional investigations of the workplace were highlighted in a recent review of the literature (Uchino *et al.*, 2012) and the present results support this position. Valuable information about the physiological consequences of work would have been overlooked had the assessment been performed at a single time point, or had the analysis relied upon an aggregation of data across both work days to provide a mean workday value. Therefore, treating physiological variation as mere 'noise' appears inappropriate in the context of the workplace. Although some occupations may be inherently more uniform than others, the workplace is generally a dynamic environment, exerting continuously changing requirements upon employees (Ilies *et al.*, 2010).

The variation in the cortisol awakening response across working days shown to occur in the present study contradicts the stability that Schlotz *et al.* (2004) found in the response across five consecutive workdays. However, as the present study required participants to select two non-consecutive work days differentiated by

their acute anticipatory demand, it is plausible that the present study sampled awakening cortisol on occasions with a greater diversity in acute anticipatory demand than would have been the case on consecutive days. Additionally the possibility that prior day's experience may have exerted an influence over the cortisol awakening response cannot be ruled out. However, it is worth noting that salivary cortisol levels were elevated in the awakening sample on the work day containing greater anticipatory demand. It is possible that this is due to awakening having occurred at a later stage in the pre-awakening diurnal rise in cortisol on the more demanding day (Wilhelm *et al.*, 2007). Alternatively, this may be indicative of greater incidence of non-adherence with the sampling protocol on the more demanding day. It has been shown that a delay between awakening and providing the awakening sample can result in an elevated initial sample (Smyth *et al.*, 2013). Although there were no incidents of self-reported non-compliance, it is impossible to determine whether the participants provided accurate information and correctly identified their awakening time.

Returning to the anticipation hypothesis, the finding that the cortisol awakening response did not differ between the less demanding work day and the weekend day suggests that the two days did not differ in anticipatory demand. What this reveals about the anticipatory demands of each day is more difficult to interpret. That is to say, the less demanding day may have been characterised by a relatively low level of demand, as would be expected to occur on a leisure day, or the leisure day may have been characterised by a relatively high level of anticipatory demand, as would be encountered on a work day. Given that academics claim to suffer from excessive workloads and to work in excess of the

weekly limit set by the UK Working Time Directive (Kinman & Court, 2010), it may be that the weekend day was more akin to a work day rather than the opposite. However, this is only speculation; it is impossible to answer this definitively as no attempt was made to quantify the demand on the work day. Fishel *et al.* (2007) reported on the importance of giving special consideration to the calibration of physiological baseline measures and the current findings demonstrate the different interpretations that can be drawn depending on how the baseline is determined.

In conclusion, the response of salivary free cortisol over the awakening period varies as a function of the relative degree of anticipatory work-related demand. Therefore, adopting an approach which considers the intra-individual variation to be meaningful, as opposed to simply 'noise' in the data, may elicit a greater understanding of the extent to which employees react and cope with the pressures of their work. This may provide a rudimentary starting point from which it is possible to move towards a model which combines subjective psychosocial questionnaires and ambulatory physiological measures into a coherent assessment of employee wellbeing. As the design parameters of the present study restricted sampling of the work-related cortisol awakening response to two days, anticipated demand was only considered in relative terms. A longer term investigation over a greater number of sampling occasions should provide a greater understanding of the extent to which the cortisol awakening response is influenced by naturally occurring variance in work-related characteristics.

Limitations: The study was based on a relatively small sample size. Additionally, the participants were recruited from within a single higher education institution

and therefore the generalisability of the findings to other employees within other institutions is unknown. The possibility of self-selection bias cannot be ruled out; employees experiencing higher levels of occupational strain may have been less likely to volunteer. In terms of the cortisol awakening response; by its very nature, i.e. being a response to awakening, it requires the moment of awakening to be correctly identified and the initial sample to be provided as close to this moment as possible. Similarly, any subsequent samples must also be provided at the correct time relative to the first sample. As the present study relied upon self-report of both the time of awakening and also of all saliva sampling times the possibility that different levels of compliance may have accounted for the observed pattern of salivary cortisol. Additionally, no attempt was made to measure the demands of the weekend day. Although a frequently used method, by only sampling cortisol at 2 time points during the awakening period it is not possible to determine whether the full extent of the cortisol awakening response was captured, nor to analyse the area under the curve. Additionally, no consideration was given to the day of the week that the work days fell on.

Contribution of the present results to the thesis.

- Further support for the existence of a clear rise in salivary free cortisol over the immediate post awakening period, with a greater response on work days than weekend days.
- Evidence that the cortisol awakening response varies according to anticipatory work-related demand.
- Confirmation of the practical and methodological challenges associated with sampling the cortisol awakening response.
- No evidence to suggest that the Health and Safety Management Standards Indicator Tool, or the Work Ability Index are associated with reactivity of the hypothalamic-pituitary-adrenal axis.
- Highlights the difficulty in establishing a relationship between stress and psychophysiological response on the basis of job characteristics.
- Demonstrates the apparent importance of attending to the dynamic nature of the workplace and within-individual variation in psychophysiology.

CHAPTER 6 – A single-subject investigation of temporal variation in heart rate variability and the cortisol awakening response with respect to acute work-related demand.

6.1 INTRODUCTION

The results presented in Chapters 4 and 5 support the theory that daily work-related experience is associated with both ambulatory heart rate variability and the cortisol awakening response at the within-subject level. Although conceptually problematic for research methodologies that simply assess stress physiology at a single time point, this very variation in response to the acute environment may contain important information regarding the physiological consequences of work. As a result, the intra-individual variation in the work-related cortisol awakening response and ambulatory heart rate variability warrants further investigation.

The methodology used in the previous chapters enabled a comparison between days of greater and lesser demand which participants had selected based upon the anticipation that they would differ. This methodology was chosen in order to increase the likelihood of sampling physiological responses on work days that differed in actual demand, without the need for extensive repeated sampling. However, it is unlikely that the full variance in physiological response to psychosocial work demand has been captured, given the limited number of sampling occasions.

Investigating physiological responses to a greater range of naturally occurring work-related stressors requires assessments to be performed over a greater number of days. However, such an approach need not necessarily require the repeated sampling of a large number of participants. Indeed, where intra-

individual variation is the dimension of interest it is, by definition, possible to perform an investigation using a single subject. This raises a longstanding psychological debate regarding the merits of the nomothetic and idiographic approaches. Allport (1937) is generally credited with introducing the terms nomothetic and idiographic to the psychological discourse, having borrowed them from the German philosopher Wilhelm Windelband. As generally applied today the nomothetic approach involves the determination of a mean value from a sample population, and deviation from this value is considered to be unwanted “noise” within the data resulting from uncontrolled variables. The idiographic approach, on the other hand, attends to the temporal variability within each case, believing this to be meaningful information. The practical distinction between the two was articulated by Skinner (1953) who, writing on human behaviour, stated that “A prediction of what the average individual will do is often of little or no value in dealing with a particular individual” (p.19). This assertion applies equally to the field of psychophysiology. Whilst humans may share a common physiology, the involvement of a cognitive component within the psychophysiological system dictates that individuals will respond differently to a given stimulus according to their unique perception and interpretation (Kristjanssen *et al.*, 2007).

Science has embraced the nomothetic approach to such an extent that idiographic research has been deemed ‘the antiscientific adversary of nomothetic progress’ (Robinson, 2011, p.35) and case study research is often vilified for lacking scientific validity. However, this commitment to the nomothetic is neither helpful nor necessary as the two approaches need not be antagonistic; they were initially conceptualised as being complementary (Salvatore & Valsiner, 2010;

Robinson, 2011). Additionally, although the inability to generalise from single-subject designs is frequently cited as a fundamental weakness of the methodology; Dermer and Hoch, (1999, p.51) point out that in reality multi-subjects designs suffer from the same shortcoming as they seldom sample from 'the universe of generalisation', instead recruiting participants from finite and selective populations. Furthermore, generalising in the opposite direction, i.e. from a group to the individual, is not without limitation as highlighted by Allport *et al.* (1937, p244) "An entire population (the larger the better) is put into the grinder and the mixing is so expert that what comes through is a link of factors in which every individual has lost his identity". Therefore, single subject research is far from redundant and represents a valid methodology when the question of interest relates to intra-individuality. Recently, single subject designs have been successfully applied to psychoneuroendocrinological investigations of the cortisol awakening response (Stalder *et al.*, 2009; Stalder *et al.*, 2010), immune function (Haberkorn *et al.*, 2013), and the sampling of stress more generally (Atz, 2013).

Experience sampling methods (Csikszentmihalyi, 1994), which involve assessing thoughts, feelings or behaviour in real time, provide a valuable tool for the modern idiographic approach to understanding individual behaviour. The main strength of all these methods is a non-reliance upon retrospective recall, avoiding multiple sources of potential bias (Smyth & Stone, 2003). For instance, individuals may overestimate the experience of daily emotions through recall, ascribe greater importance to recent events in comparison to more distant ones, and place undue emphasis upon the magnitude of the most intense experience of a specific

episode at the cost of duration or frequency with which events occur (Stone *et al.*, 2005).

The present study was designed with the intention of building upon the findings of chapters four and five, by performing repeated measurements at the intra-individual level using an experience sampling methodology, but also on much of the existing literature by controlling for adherence with cortisol sampling protocol. An additional benefit of the repeated measures approach is that it allows investigation of relationships between variables that may not share a common time course. For instance, although the anticipation hypothesis asserts that the cortisol awakening response is a reaction to the demand of the upcoming day, there is some evidence that prior day's adverse psychosocial experiences are also implicated in this response. Anxiety (Dahlgren *et al.*, 2009), loneliness (Adam *et al.*, 2006; Doane & Adam, 2010), sadness and threat (Adam *et al.*, 2006) have all been shown to demonstrate an association with cortisol on the following morning. Therefore, it seems plausible that the cortisol awakening response may also demonstrate an association with work-related psychosocial factors over the preceding working day. Similarly, if heart rate variability varies according to the demands of the working day, it follows that prior day's heart rate variability and the cortisol awakening response may be related.

In summary, the aim of the present study was to investigate intra-individual variation in measures of heart rate variability and the cortisol awakening response with respect to acute psychosocial characteristics. The hypotheses were threefold: i) heart rate variability and the cortisol awakening response would

demonstrate variation according to both the nature of the assessment day and psychosocial work-related factors; ii) the cortisol awakening response would be associated with prior day's work-related psychosocial factors; and iii) the cortisol awakening response would be associated with prior day's ambulatory heart rate variability.

6.2. METHODS

Full details regarding the participant are provided in section 3.2.2 and the general procedure is outlined in section 3.4.5. Additionally, the following specific methods of data analysis were applied.

Determination of sleep, awakening times and sampling times:

Onset of sleep was deemed to occur at the point where ten minutes of consecutive activity counts of zero were recorded (Izawa *et al.*, 2010). In total, three measures of awakening time were obtained: the time written on the Salivette tubes, the time stamp provided by the MEMS smart cap, and awakening time identified by a sudden simultaneous increase in both HR and activity counts. Sampling times were obtained by uploading data from the MEMS smartcap into an Excel spreadsheet via Powerview software (Aardex Ltd., version 1.4.0; 2001)

Segmentation of Day:

Sleep was identified as the entire period between onset of sleep and awakening. The daytime segment was quantified as commencing at 08.00 and terminating at

18.30, as these times represent the points at which the participant generally left for work and returned home. Evening was therefore the period from 18.30 until sleep.

Statistical Analysis:

A repeated measures ANOVA was performed to investigate the response of salivary cortisol to awakening. To compare responses on different types of day i.e. work, research and weekend this was repeated with day entered as a between-subjects factor. Bivariate correlational analyses were then performed to examine the relationship between measures of cortisol and measures of psychosocial work strain. Further bivariate correlational analyses were carried out to examine the relationship between measures of heart rate variability and measures of cortisol. Where the Shapiro-Wilk test revealed the assumption of normality had not been met Spearman's correlations were used, and in all other case Pearson's correlations were performed. One sample t-tests were performed on sampling times to examine adherence with protocol. Differences in heart rate variability across the course of the day were investigated by means of a repeated measures ANOVA, which was repeated with type of day entered as a between-subjects factor.

6.3 RESULTS

Psychosocial work-related characteristics are presented in Table 6.1. The participant perceived the mean level of work-related demand over the duration of the study to be lower than the demand to which they are generally exposed; the mean score on the visual analogue scale was 3.85 whereas the midpoint of 5 on the scale represents an average level of demand. The participant reported a higher score for positive affect (22.56) compared to negative affect (11.82), which is normal (both scales have a potential scoring ranges from 5-50, with higher scores representing greater affect). All work-related psychosocial characteristics demonstrated variation across the study, with workload ranging from 11.75 to 22.56, work-related demand ranging from 1.90 to 5.60, positive affect ranging from 17.48 to 27.00 and negative affect ranging from 10.00 to 16.50 (Table 6.1).

Table 6.1. Psychosocial work-related characteristics

	Mean	Min	Max
Work –related demand	3.85.	1.90	5.60
Workload	17.48	11.75	23.00
Positive affect	22.56	15.00	27.00
Negative affect	11.82	10.00	16.50

Associations between all questionnaire based constructs are presented in Table 6.2. The two opposing dimensions of the affect scale were negatively associated ($r=.543$, $p<.05$). Workload demonstrated a positive association with positive affect

($r=.553$, $p<.05$) and a negative association with negative affect ($r=-.274$ $p<.05$).

Demand was positively associated with negative affect ($r=.552$, $p<.05$).

Table 6.2. Associations between questionnaire measures

	1	2	3
	r= (p-value)	r= (p-value)	r= (p-value)
Demand (1)	-	-	-
Workload (2)	.218 (.435)	-	-
Positive Affect (3)	-.020 (.944)	.553 (.032*)	-
Negative Affect (4)	.552 (.033*)	-.274 (.323)	-.543 (.037*)

* denotes a significant correlation $p<.05$

Mean values of activity, heart rate and heart rate variability, according to time of day, are presented in Table 5.3. There was an effect of time on average interbeat interval ($F [2,34] = 50.56$, $p<.001$, partial eta squared = .748) standard deviation of normal-to-normal interval ($F [2,34] = 17.92$, $p<.001$, partial eta squared .513) root mean square of successive differences ($F [2,34] = 22.04$, $p<.001$, partial eta squared .565) high frequency power ($F [2,34] = 9.41$, $p<.001$, partial eta squared .356) and the LFHF ratio ($F [2, 34] = 40.43$, $p<.001$, partial eta squared .704) Pairwise comparisons revealed no parameters of heart rate variability differed between daytime and evening. However, heart rate and the low-to-high frequency ratio were significantly lower during sleep than during work time or evening whilst average interbeat interval, standard deviation of NN intervals, root mean square of successive differences and HF power were all greater during sleep time compared with day time and evening values.

Table 6.3. Physiological and motility data according to time of day.

	Work time		Evening		Nocturnal	
	Mean	SD	Mean	SD	Mean	SD
Activity	56.14	34.59	26.64	15.75*	0.45	0.44*†
HR	68.40	16.55	66.67	10.26	50.52	2.72*†
Ave IBI	933.56	120.52	934.31	114.30	1191.13	62.10*†
SD	82.21	18.72	85.02	20.50	107.92	15.91*†
RMSSD	69.48	25.93	76.79	25.46	109.76	20.44*†
LF	3768.16	2564.90	3165.65	2204.21	2316.41	994.30
HF	2378.04	3191.35	1993.84	1605.28	3277.48	1898.72*†
LFHF	2.95	0.82	2.64	0.85	1.02	0.44*†

Daytime = 08.30 – 18.30, Evening = 08.30 – onset of sleep, Nocturnal = onset of sleep – awakening. Activity (movement counts), HR (bpm), Ave IBI = Average interbeat interval (m/s) SD = (standard deviation of RR interval (ms), RMSSD = Root mean square of successive differences, LF = low frequency power (ms²), HF = high frequency power (ms²), LFHF = low to high frequency ratio. * denotes significant difference from daytime (P<.05) † denotes significant difference from evening value.

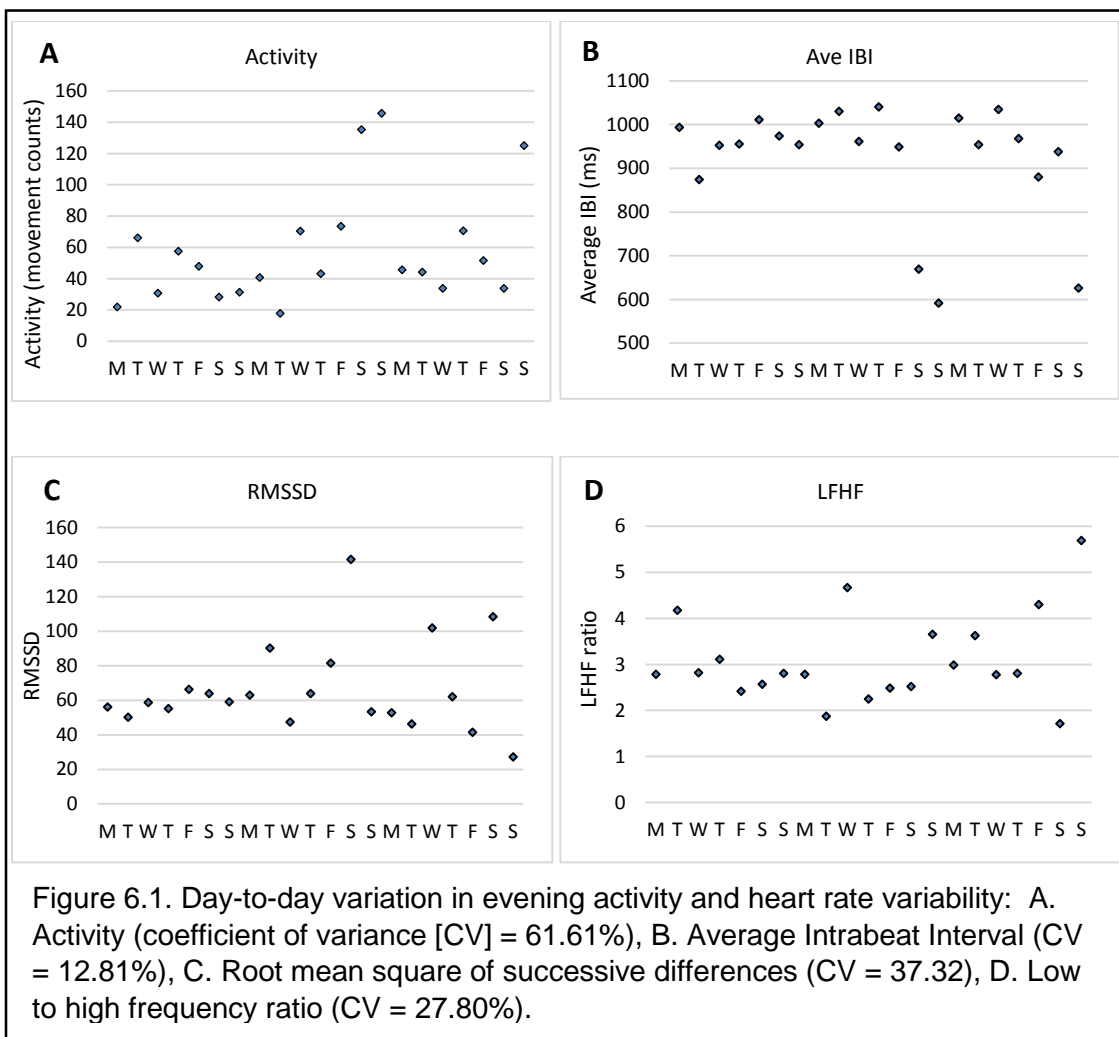
Mean values for all physiological measures according to the nature of the day are presented in Table 6.4. Type of day has no effect upon activity (F [1.04, 5.31] = 3.06 p>.10, partial eta squared .379) heart rate (F [1.07, 5.33] = 5.19, p>.05, partial eta squared .509) area under the curve with respect to increase (F [2,10] = 1.24, p>.10, partial eta squared .199) area under the curve with respect to ground (F [1.46, 7.30] = .757 p>.10, partial eta squared .131) or any parameters of heart rate variability.

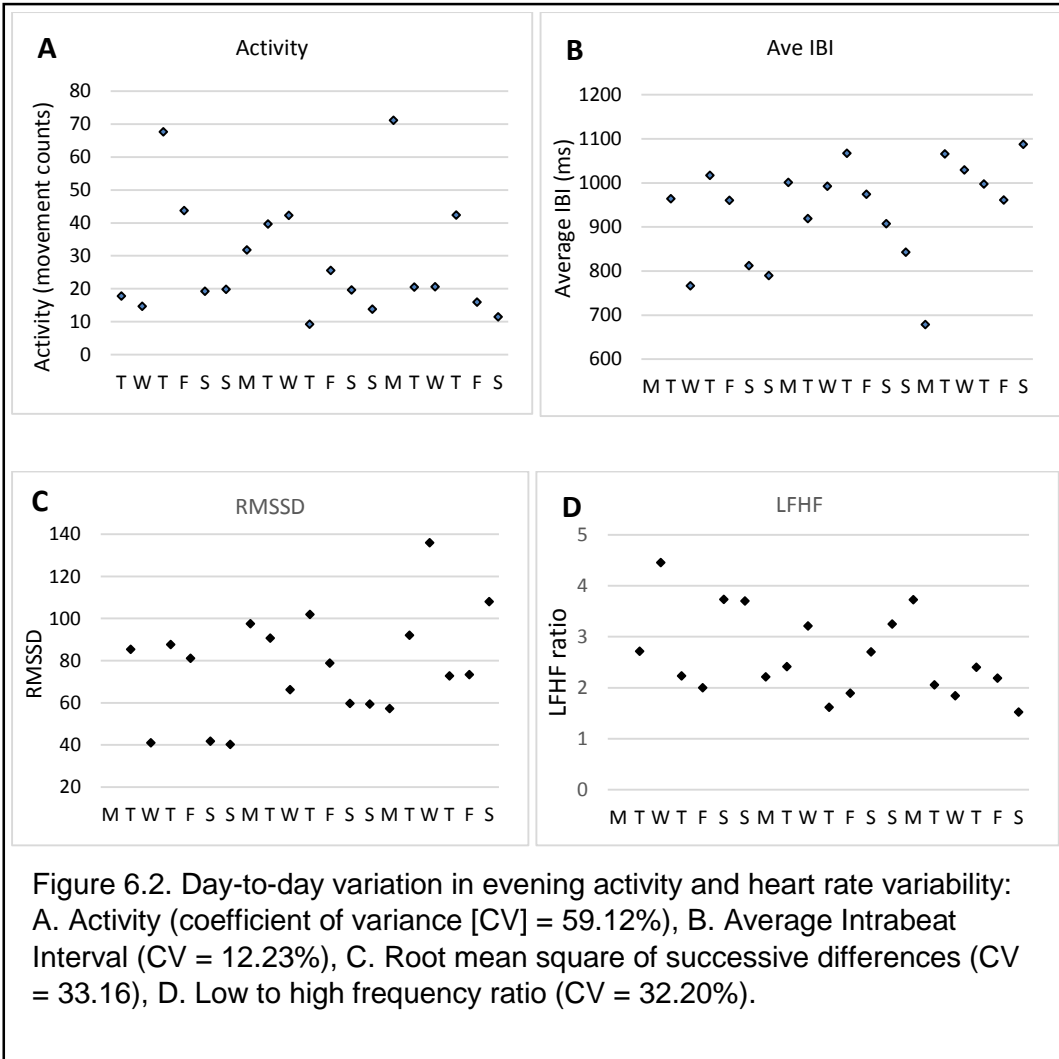
Table 6.4. Daytime Physiological and motility data according to characteristics of measurement day.

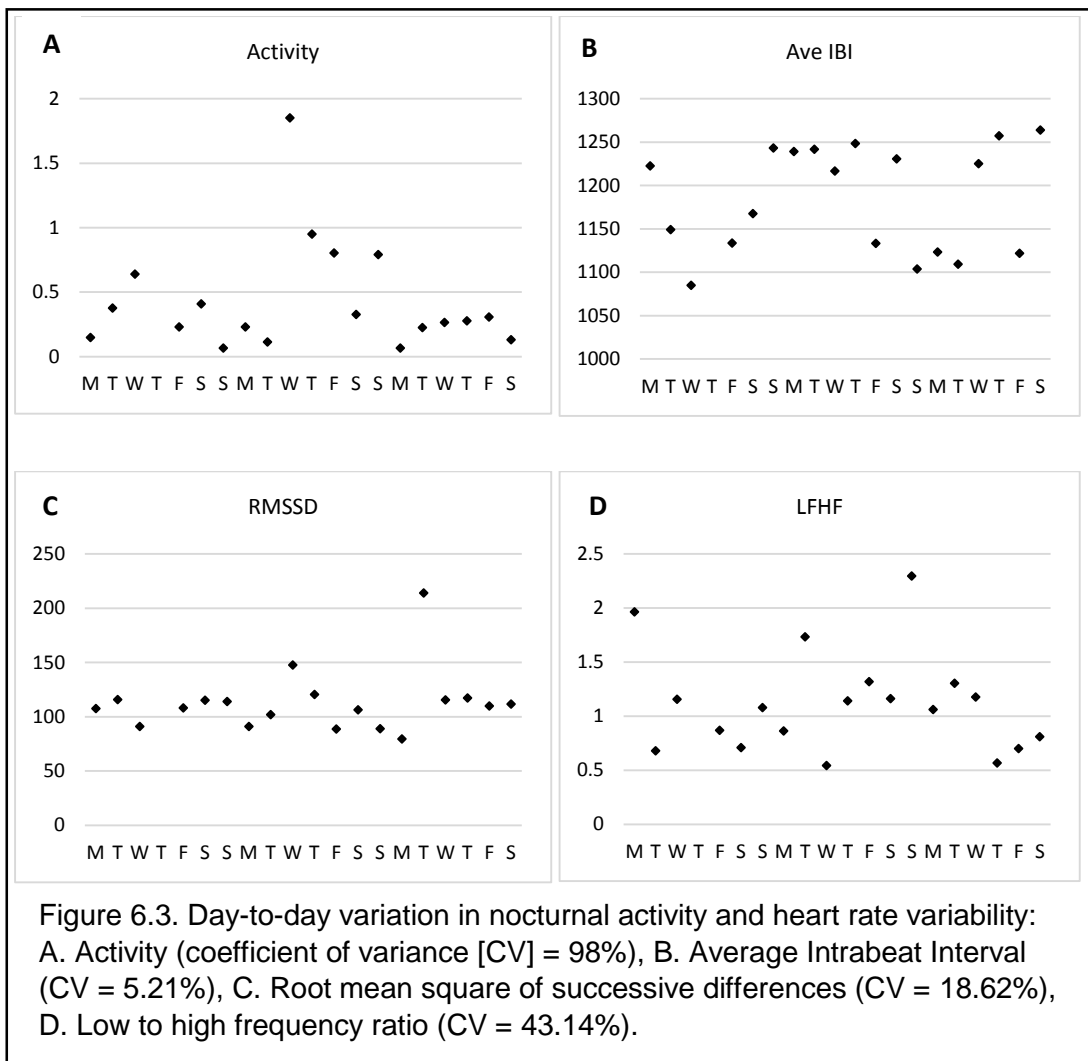
	Work Day		Research Day		Weekend	
	Mean	SD	Mean	SD	Mean	SD
Activity	41.18	19.02	51.34	17.90	86.00	60.79
HR	62.07	4.56	63.22	3.23	87.97	26.41
Ave IBI	983.18	60.93	964.98	54.24	788.50	184.02
SD	77.64	10.41	82.08	15.66	76.85	24.00
RMSSD	63.00	14.22	66.19	22.46	68.33	30.15
LF	2171.95	712.49	2874.76	1457.37	3487.57	2630.04
HF	1186.84	821.07	1803.47	1685.39	2625.68	2233.05
LFHF	2.83	0.79	3.24	0.98	3.19	1.37
AUC _(g)	1155.08	728.51	942.06	481.64	1071.95	352.12
AUC _(i)	559.54	695.71	291.05	321.57	445.45	266.25

Work – workday, Research = study day Weekend = Sat/Sun. Activity(movement counts), HR(bpm), Ave IBI = Average interbeat interval (m/s) SD =(standard deviation of RR interval (ms), RMSSD = Root mean square of successive differences, LF = low frequency power (m/s), HF = high frequency power (m/s), LFHF = low to high frequency ratio, AUC(g) = area under the curve with respect to ground, AUC(i) = area under the curve with respect to increase.

Visual inspection of the data revealed that physical activity and measures of heart rate variability demonstrated substantial day-to-day variability. The variation in activity, the average interbeat interval, root mean square of successive differences and the LFHF ratio are shown below for daytime (Figure 6.1), evening time (Figure 6.2) and sleep time (Figure 6.3). Different scales are used across the three time points to better illustrate the variation occurring with respect to that part of the day, i.e. between, rather than within, days.







Values of sleep related factors and cortisol sampling times are presented in Table 6.5. The mean awakening time was 06.52 ± 30 mins. The time between providing the first and second samples was 31.51 minutes (protocol = 30 minutes) and the time between samples two and three was 16.03 (protocol = 15 minutes). However, as the differences between the protocol times and the sampling times did not differ significantly, any subsequent references to salivary free cortisol values at specific time points will reflect the protocol, i.e. 0 minutes, 30 minutes and 45 minutes.

Table 6.5. Sleep and sampling-related measures.

	Mean	SD
Awakening time	06:51	00:31
Sleep Duration (hrs.mins)	07:00	00:45
Sample time (1-2)*	31:51	04:09
Sample time (2-3)*	16:03	04:04
Sample time (1-3)*	47:54	06:50

Values from 20 study days. * Timings determined from MEMS smartcap device

Salivary cortisol demonstrated a clear awakening response with levels increasing from 13.50 nmol/l at awakening to 25.06 nmol/l thirty minutes later and continuing to increase to 31.71 nmol/l forty five minutes post-awakening (Figure 6.4). The effect of time was found to be significant ($F[2, 40] = 14.076, p < .001$, partial eta squared .482) and pairwise comparisons revealed significant differences between all time points demonstrating that salivary free cortisol values increased significantly from 0 to 30 minutes and again from 30 to 45 minutes post awakening.

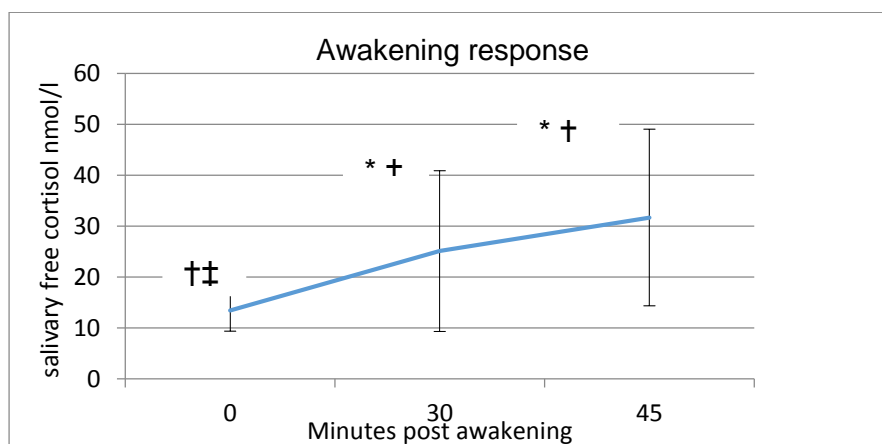


Figure 6.4. Mean cortisol awakening response over all study days. * = Significantly different from 0, † = significantly different from 30, ‡ = significantly different from 45.

An awakening response was evident on all 21 study days with levels of salivary cortisol increasing from awakening to 30 minutes post-awakening (Figure 5.5). A further increase in salivary cortisol from 30 to 45 minutes post awakening was found to occur on over 70% of occasions. The peak cortisol value over the entire study was 82nmol/l.

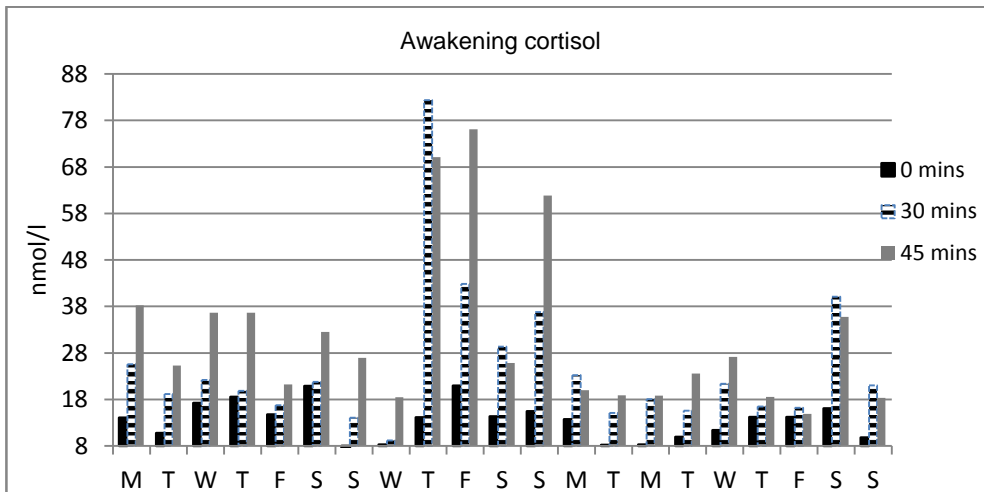


Figure 6.5. Day-to-day variation in awakening cortisol response. Salivary free cortisol (nmol/l) at 0, 30, and 45 minutes post awakening

The results of the between-days analysis failed to identify a difference in the dynamic of awakening cortisol between the weekday and the weekend ($F [1, 19] = 22.626, p = .88$). Similarly, no differences were found to exist according to the type of day, i.e. work/PhD/weekend ($F [4, 36] = .303, p = .874$) (Figure 6.6).

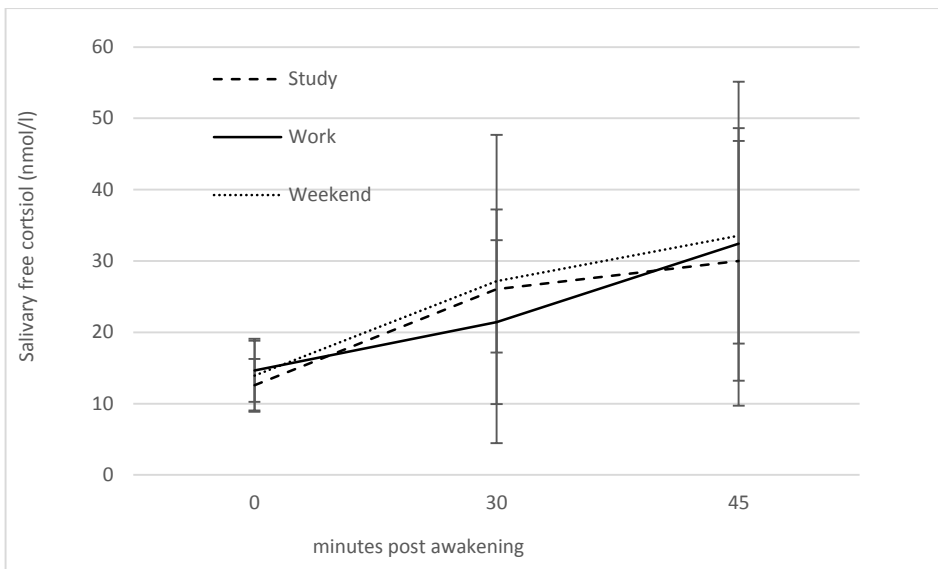


Figure 6.6. Cortisol awakening response according to characteristics of study day.

Prior day's perceived workload demonstrated a negative association with the area under the curve with respect to both ground ($r = -.558, p < .05$) and the increase ($r = -.668, p < .001$) (Table 6.6). Same day negative affect was also associated with both areas under the curve ($r = -.622, p < .05$ and $r = -.703, p < .05$) for ground and increase respectively. Same day demand demonstrated a negative association with the area under the curve with respect to increase ($r = -.743, p < .05$).

Table 6.6. Relationship between questionnaire responses and awakening cortisol

	Sample 1	AUC _g	AUC _i
	R (p-value)	R (p-value)	R (p-value)
<i>Same Day</i>			
Positive Affect	.140 (.620)	.250 (.368)	.143 (.611)
Negative Affect	-.199 (.477)	-.622 (.013*)	-.703 (.003*)
Workload	.447 (.095)	.296 (.284)	-.054 (.849)
Demand	.111 (.694)	-.428 (.112)	-.743 (.002*)
<i>Prior Day</i>			
Positive Affect	.295 (.306)	-.084 (.776)	-.099 (.736)
Negative Affect	-.022 (.940)	.029 (.922)	-.210 (.471)
Workload	-.049 (.869)	-.558 (.038*)	-.668 (.009)
Demand	.152 (.605)	.099 (.844)	-.253 (.383)

* denotes significance $p < .05$ ** denotes significance $p < .001$. AUC_g: Area under the cortisol curve with respect to ground, AUC_i: Area under cortisol curve with respect to increase.

The value of salivary free cortisol on awakening was not associated with parameters of heart rate variability, either in the time or frequency domain on the previous day and there was no association between the dynamic of the awakening cortisol response and prior day's heart rate variability (Table 6.7). Additionally, no measures of the cortisol awakening response were associated with any parameters of heart rate variability on the same day.

Table 6.7. Associations between prior day's HRV and awakening cortisol.

	Sample 1	AUC _g	AUC _i
	R (p-value)	R (p-value)	R (p-value)
<i>Prior Day</i>			
Heart rate	.009 (.730)	-.001 (.801)	-.106 (.628)
Ave IBI	.013 (.205)	.073 (.420)	.199 (.184)
SD	.053 (.646)	.350 (.970)	.441 (.670)
RMSSD	-.117 (.486)	.253 (.861)	.412 (.205)
LF	-.156 (.955)	.079 (.830)	.352 (.235)
HF	-.309 (.269)	-.009 (.680)	.307 (.254)
LF/HF	.158 (.278)	-.181 (.207)	-.315 (.114)
Activity counts	.152 (.667)	.009 (.700)	-.125 (.563)
<i>Prior night</i>			
Heart rate	.224 (.143)	-.098 (.736)	-.390 (.529)
Ave IBI	-.283 (.113)	.044 (.619)	.334 (.125)
SD	.219 (.280)	.292 (.229)	.302 (.439)
RMSSD	.183 (.466)	.228 (.177)	.253 (.353)
LF	-.031 (.207)	.108 (.746)	.262 (.416)
HF	.347 (.835)	.260 (.395)	.115 (.671)
LF/HF	-.207 (.356)	.005 (.489)	.074 (.680)
Activity counts	.241 (.830)	.141 (.667)	.168 (.471)

AUC_g: area under cortisol curve with respect to ground, AUC_i: area under cortisol curve with respect to increase, AVE IBI: average interbeat interval, SD: standard deviation of normal to normal interval, RMSSD: root mean square of successive differences, LF: low frequency power (ms), HF: High frequency power (ms), LF/HF: ratio of low to high power, Activity Counts: (arbitrary units)

Associations between questionnaire data and heart rate variability over the course of the day are presented in Table 6.8. Neither work-time affect, measured by the PANAS, nor self-rated workload were related to any parameters of heart rate variability at any stage of the day. However, perceived acute demand was

found to be associated negatively with the root mean square of successive differences ($r=-.560$, $p<.05$) and positively with the LFHF ratio ($r=.616$, $p<.05$) during work time, suggesting that greater work-related demand is associated with vagal withdrawal and a shift towards sympathetic dominance of the autonomic nervous system during working hours. Additionally, acute demand demonstrated negative associations with the standard deviation of normal NN intervals ($r=.642$, $p<.05$), the root mean square of successive differences ($r = .739$, $p<.001$), low frequency power ($r = -.710$, $p<.001$), high frequency power ($r=-.761$, $p<.001$) and a positive association with the LFHF ratio ($.637$, $p<.05$) in the evening.

Table 6.8 Associations between psychosocial and physiological variables.

	Positive Affect R (p-value)	Negative Affect R (p-value)	Workload R (p-value)	Demand R (p-value)
<i>Work time</i>				
Heart rate	.116 (.680)	-.154 (.583)	.005 (.985)	.326 (.236)
Ave IBI	-.208 (.458)	.176 (.531)	-.034 (.904)	-.358 (.190)
SD	-.279 (.314)	.158 (.574)	-.013 (.965)	-.462 (.083)
RMSSD	-.250 (.368)	.014 (.960)	.022 (.939)	-.560 (.030*)
LF	-.388 (.153)	.152 (.587)	-.118 (.674)	-.371 (.174)
HF	-.247 (.375)	.013 (.965)	.118 (.674)	-.480 (.070)
LF/HF	.093 (.742)	.127 (.651)	-.036 (.899)	.616 (.014*)
Activity	-.143 (.611)	-.086 (.760)	.007 (.980)	.007 (.310)
<i>Evening</i>				
Heart rate	.343 (.230)	.150 (.608)	.137 (.640)	.368 (.195)
Ave IBI	-.304 (.291)	-.201 (.491)	-.119 (.684)	-.450 (.107)
SD	-.214 (.731)	-.298 (.301)	-.214 (.462)	-.642 (.013)
RMSSD	-.250 (.517)	-.214 (.462)	-.250 (.389)	-.739 (.003**)
LF	-.354 (.664)	-.168 (.566)	-.354 (.215)	-.710 (.004**)
HF	-.212 (.497)	-.152 (.603)	-.212 (.467)	-.761 (.002**)
LF/HF	.263 (.441)	.252 (.385)	.263 (.364)	.637 (.014*)
Activity	.213 (.464)	.208 (.477)	.398 (.159)	.298 (.301)
<i>Nocturnal</i>				
Heart rate	.414 (.141)	-.025 (.931)	.162 (.581)	.466 (.093)
Ave IBI	-.355 (.213)	.056 (.848)	-.117 (.689)	-.411 (.144)
SD	-.293 (.309)	.231 (.427)	-.419 (.136)	.014 (.961)
RMSSD	-.240 (.408)	.218 (.455)	-.308 (.284)	-.092 (.756)
LF	-.346 (.226)	.215 (.459)	-.250 (.388)	-.237 (.415)
HF	-.143 (.625)	.160 (.584)	-.151 (.607)	-.133 (.649)
LF/HF	-.040 (.893)	-.257 (.374)	-.051 (.863)	-.453 (.104)
Activity	.067 (.819)	-.071 (.810)	-.316 (.271)	-.035 (.905)

* Denotes significant correlation, $p < .05$ ** $p < .01$

6.4 DISCUSSION

This study was performed to investigate intra-individual variation in ambulatory heart rate variability and the cortisol awakening response in relation to acute psychosocial factors. It was hypothesised that: i) heart rate variability and the cortisol awakening response would demonstrate variation according to both the nature of the assessment day and to psychosocial work-related factors; ii) the cortisol awakening response would be associated with prior day's work-related psychosocial factors; and iii) the cortisol awakening response would be associated with prior day's ambulatory heart rate variability. Although a clear awakening response was observed on all study days, there was substantial day-to-day variation in measures of absolute cortisol and in the dynamic of the release during the awakening period across the study. This adds to the growing body of evidence which suggests that the cortisol awakening response is influenced by situation specific factors rather than representing a stable biological response (Matsuda *et al.*, 2012; Ross *et al.*, 2014). Similarly, heart rate variability was also shown to vary significantly over time. Although acute demand and workload were both associated with heart rate variability, no parameters of heart rate variability or of the cortisol awakening response were found to differ according to the nature of the assessment day. Therefore the results offer partial support for the first hypothesis of the study. The cortisol awakening response demonstrated an association with prior day's workload, supporting hypothesis ii, but not with prior day's heart rate variability, leading to a rejection of hypothesis iii.

Neither heart rate variability, nor awakening cortisol, differed according to the nature of the day. The results presented in chapters 4 and 5 of this thesis suggest

that higher levels of acute demand are associated with enhanced sympathetic dominance of the autonomic nervous system and with a greater cortisol awakening response. Viewed together with the present findings, this suggests that the magnitude of perceived demand may be of greater importance in terms of the physiological response to work than the nature of the working day. Additionally, the possible influence of prior days experience upon the cortisol awakening response was acknowledged as a possibility in chapter 5 and the present findings support this possibility.

Previous reports of a reduced cortisol awakening response at the weekend are usually interpreted as evidence of lesser demand on weekend days, which appears a reasonable assumption. The present study did not include a measure of acute demand at the weekend, so cannot infer whether weekday and weekend days differed in perceived demand. In a similar single-subject study, Stalder *et al.* (2010) failed to detect any differences between awakening cortisol on weekdays and weekend days at the within-subject level, which was attributed to a lack traditional differentiation between week days and weekend days as a result of not following a normal working pattern. Whilst the participant in the present study followed a traditional weekday/weekend working pattern, one weekend included in the assessment period contained a naturalistic stressor in the form of participation in a sporting competition.

The anticipatory demands of competitive sport can be substantial, and participation in competitive sport has been shown to elevate levels of cortisol in

the period immediately prior to competition (Salvador *et al.*, 2003; Alix-Sy *et al.*, 2008). The results of the present study support this, as the increase in cortisol on the day of the competition was greater than occurred on the other weekend days. However, the cortisol response was also found to be elevated over the three day period prior to the day of the event. There are a number of factors that may have contributed to the presence of this earlier response, which relate to the individual's appraisal of the competition. Athletes' anticipatory responses are largely determined by whether they perceive a competition to represent a challenge or a threat; challenge elicits a positive response whilst the threat results in a negative response (Jones *et al.*, 2009). Threat appraisals occur when an event presents danger, either to health or self-esteem (Quested *et al.*, 2011) and have been shown to be a significant predictor of the cortisol response (Gaab *et al.*, 2005). Similarly, a perceived lack of competence increases the likelihood that resources are viewed as being inadequate, resulting in a sense of pressure and apprehension (Quested *et al.*, 2011). As mountain biking is an inherently dangerous sport and the participant had no prior experience of competitive enduro racing against which to measure their competence, it seems likely he would have appraised the competition as a threat. Furthermore social evaluation in competitive situations has also been shown to elevate cortisol levels (Rohleder *et al.*, 2007) and the nature of enduro racing, which allows participants to compete against their peers on the same course, could be perceived to contain a degree of social evaluation. Therefore the unique combination of novelty, danger, uncontrollability, the unknown and social evaluation may have led to a negative cognitive appraisal of the competition which may have contributed towards the magnitude and timing of elevated salivary cortisol.

Turning to the work-related psychosocial factors; the inverse association between prior day's workload and the dynamic of cortisol suggests that acute exposure to higher workload suppresses the reactivity of the hypothalamic pituitary adrenal axis the following day. Although the effects of workload have previously been shown to affect family conflict, and thus to spill over into the non-work domain (Ilies *et al.*, 2007), the current study appears to be the first study to reveal an association between workload and the cortisol awakening response on the following day. However, similar effects have been found for other types of acute psychosocial experience (Adam *et al.*, 2006; Dahlgren *et al.*, 2009; Doane & Adam, 2010). Taken together this evidence results suggest that the anticipation hypothesis may not adequately account for the rapid increase in salivary free cortisol over the awakening period.

Although workload had no effect upon heart rate variability, the participant's perception of daily demand was found to be associated with vagal withdrawal and enhanced sympathetic dominance of the autonomic nervous system, both during work-time and evening leisure time. Therefore, the participant's subjective appraisal of the global demand of their working day mirrors the pattern of autonomic function. Whilst the association between acute demand and physiological measures associated with the stress response is far from being a novel finding, there is no previous evidence to suggest that a subjective appraisal of work-related demand relative to what is typical, is related to ambulatory heart rate variability (with the exception of the results presented in chapter 3). Although it is not possible to establish causality, the fact that this unidimensional measure of acute demand may provide the means to differentiate between days according

to the response of the autonomic nervous system is promising. In terms of conducting real world ambulatory assessment, the fact that an employee's perception of the acute demands of the day correlate to the sympathovagal balance of the autonomic nervous system may provide a valuable means to calibrate how representative the sampling day is. Therefore, rather than merely being able to assert that on a specific work day a participant demonstrated a certain level of sympathovagal balance, attending to acute demand may provide a context within which the physiological response can be viewed. As the measure of demand applied in the present study has not been used by other researchers, it remains unclear exactly what is being measured. Certainly, the lack of specificity of the question "*how demanding was your day, compared to an average day?*" relies upon subjective interpretation of what constitutes daily demand. It is possible that because demand is not being attributed to a particular dimension, or work-characteristic, the answer provides a more holistic appraisal of the work-related psychosocial environment. Alternatively, many psychosocial factors known to contribute to the experience of stress are relatively stable. It has been argued that control, which according to the job-demand-control model (Karasek, 1979) is a fundamental determinant of the experience of work-related stress, is a fairly stable construct (Ilies *et al.*, 2010). Therefore, at the intra-individual level it follows that acute demand would be expected to exert a significant influence upon the perception of the environment. Although the current trend is to devise increasingly more complex models to account for the manifold factors that could contribute to an individual perceiving their environment unfavourably (the numerous revisions to the job demand control model being a prime example), such an approach arguably cannot adequately account for all

potential variables. Perhaps, therefore, attending to perception of some global 'demand' at an individual level is an equally useful approach in real world settings.

There are some points of note relating to the awakening cortisol response observed across this study; specifically the magnitude and timing of responses. Although the peak value of salivary cortisol in the present study is higher than generally reported during awakening, this can be explained by the fact that the cross-sectional nature of most previous investigations leads to the reporting of mean values aggregated across individuals; the actual magnitude of variation occurring within individuals is seldom reported. However, in their single-subject case study, Stalder *et al.* (2010) found salivary cortisol to range from 1.4nmol/l to 48.4 nmol/l over the awakening period, whilst Matsuda *et al.* (2012) reported the increase in cortisol over the awakening period to range from approximately 5 nmol/l to 65 nmol/l across measurement occasions. Certainly, the maximum value of salivary free cortisol observed in the present study is within the bounds of those shown to occur within single participants (Cook *et al.*, 1999; Preussner *et al.*, 1997) with values in excess of 100 nmol/l having been reported (Hellhammer *et al.*, 2009). However, it is important to note that the relationship between plasma and salivary cortisol is non-linear, with the ratio being 1-2% in the lower range and 8-9% in the upper range (Hellhammer *et al.*, 2009). Therefore, increases in plasma cortisol at higher concentrations result in a disproportionately large increase in salivary cortisol (Levine *et al.*, 2007).

Additionally, on approximately 70% of measurement occasions, levels of salivary free cortisol continued to demonstrate an increase from 30 to 45 minutes post-awakening. This is worthy of note, as the exact time-frame over which salivary cortisol levels reach their peak following awakening is currently unclear. Several studies have reported that values decrease from 30 to 45 minutes post awakening (Wilhelm *et al.*, 2007; Mikolajczak *et al.*, 2009; Stalder *et al.*, 2010), whilst others have shown values to continue to increase until 45 minutes post awakening (Thorn *et al.*, 2009). Much of the variation in the timing of peak cortisol has previously been attributed to possible non-adherence with the sampling protocol, i.e. where a participant's reported time of awakening is later than the actual awakening time the peak cortisol value will demonstrate a shift towards earlier time points. However, the finding that the participant in the present study demonstrated a variation in the time course of the cortisol curve suggests that the variation may be a genuine physiological phenomenon and not simply sampling error. There is currently no understanding of what represents a normal curve (Mikolajczak *et al.*, 2009), but it is possible that the time to peak value contains important information. Irrespective of the interpretation of, or mechanisms behind the timing of peak cortisol, the apparent variability in the timing of the response may conceal the full extent of the awakening in cross-sectional research where participants respond at different rates. Aggregating the data could result in early and late peak values attenuating the magnitude of the response.

Conclusion:

Ambulatory heart rate variability and the cortisol awakening response both demonstrate substantial day-to-day variability at the within-individual level. Acute

work-related demand is associated with enhanced sympathovagal balance of the autonomic nervous system both during work time and in the evening. Daily workload is negatively associated with the dynamic of salivary cortisol over the awakening period on the following day. These results support the assertion that the dynamic nature of the workplace requires that any psychophysiological ambulatory assessment be conducted on more than one occasion. Additionally, attending to the variation in physiological functioning rather than attempting to establish a trait measure may prove a fruitful avenue for future research into the relationship between psychosocial stress and negative health outcomes.

Limitations

Although multiple measures were employed to assess the psychosocial state characteristics encountered during working hours, no assessment was made of similar characteristics throughout the remainder of the day which could reasonably be expected to influence the following day's CAR. Additionally, as the present study did not capture information pertaining to the anticipated demand of the day ahead it is possible that the association between prior day's workload and the awakening cortisol the following day results from a relationship between workload on concurrent days. However, as there were only 3 occasions on which the participant performed the same role on consecutive days, this seems unlikely. As with all idiographic research the results of the present study cannot be extrapolated to a wider population, but rather should serve as a starting point with further research being needed to investigate whether the findings can be replicated in other individuals.

Contribution of the present results to the thesis.

- Further support for an increase in salivary cortisol over the awakening period.
- Evidence of substantial within-individual variation in the cortisol awakening response.
- Evidence of substantial within-individual variation in ambulatory heart variability.
- Acute work-related demand was associated with ambulatory heart rate variability during work time and evening time.
- Workload was associated with following day's cortisol awakening response.
- The type of day, i.e. work/research did not affect heart rate variability of the cortisol awakening response. Further evidence that a subjective rating of acute work-related demand using a visual analogue scale reflects the balance of the autonomic nervous system.

CHAPTER 7. Ambulatory monitoring of blood pressure and heart rate variability: the influence of concurrent work-related physical activity.

7.1 INTRODUCTION

The findings presented in the preceding chapters add to the evidence that both heart rate variability and the cortisol awakening response demonstrate substantial day-to-day variability at the within-individual level. Furthermore, this variation appears, to some extent, to reflect individual perception of the psychosocial environment, with specific reference to the level of acute work-related demand. As a result any attempt to investigate the psychophysiological consequences of work should consider attending to acute variation, both in the work environment and in the responses of the hypothalamic pituitary adrenal axis and the autonomic nervous system. However, by its very nature a repeated measures approach requires that attention not only be given to change in the variable of interest, but also to potential confounding variables (Seltman, 2013).

This, and the following chapter, will therefore investigate the extent to which variation in certain additional factors influence ambulatory heart rate variability and the cortisol awakening response. The present chapter will focus upon the potential for moderate levels of work-related physical activity to influence ambulatory blood pressure and heart rate variability. Chapter 7 will attend to potential sleep-related factors which may influence the awakening cortisol response as well as the possible synchronicity between heart rate variability and cortisol over the awakening period.

Exercise elicits a concomitant increase in heart rate and a shortening of the R-R interval, which has been shown to demonstrate a marked deflection point, coinciding with the lactate and ventilatory thresholds (Karapetian, 2008).

Therefore, time domain metrics of heart rate variability, which are derived from the R-R interval, are similarly affected by exercise (Osterheus *et al.*, 1997; Banach *et al.*, 2004; Torres *et al.*, 2008). As the R-R interval is controlled by dual inputs from the sympathetic and parasympathetic nervous system, any variation in the interval originates from alterations to these inputs (Pumprla *et al.*, 2002). There are conflicting reports of the reduced R-R interval being elicited by vagal withdrawal (Tulppo *et al.*, 1998), or an increase in sympathetic activity (Perini & Veicsteinas, 2003). A potential explanation for these discrepancies may be provided by the fact that the shortening of the R-R interval during exercise appears to be affected by a biphasic response of the autonomic nervous system. At relatively low levels of exercise, vagal withdrawal is primarily responsible for the acceleration of heart rate, whilst at higher intensities sympathetic input becomes progressively more responsible (Orizio, 1988; Robinson *et al.*, 1996). The initial vagal withdrawal is generally observed up to intensities of around 50-60% of maximal oxygen consumption, after which point sympathetic activity predominantly influences the R-R interval. Therefore, this turning point, often referred to as the heart rate variability threshold, appears to coincide with the anaerobic threshold (Park *et al.*, 2014). Indeed, a disproportionate change in sympathovagal balance has been shown to occur around the anaerobic threshold and several studies have demonstrated that thresholds for various metrics of heart rate variability correspond with lactate and ventilatory thresholds (Anosov *et al.*, 2000; Cottin *et al.*, 2006; Cottin *et al.*, 2007; Karapetian *et al.*, 2008; Garcia-Tabar *et al.*, 2013; Park *et al.*, 2014).

The interpretation of heart rate variability as a measure of psychosocial stress based upon an ambulatory recording which includes periods of exercise is clearly

problematic. However, out with the world of professional sport, there are relatively few occupations that will regularly require employees to operate at relatively high levels of physical activity. However, the shift towards sedentary occupations has substantially decreased the physical component of work resulting in low physical workloads for many workers (Straker and Mathiassen, 2010). Therefore, the extent to which these low physical workloads may also exert an influence over ambulatory heart rate variability remains an important issue if heart rate variability is to serve as a marker of the stress response to work.

Several attempts have been made to investigate the influence of relatively moderate levels of activity upon heart rate variability, predominantly through experimental means, either in the laboratory or by manipulating activity in a more naturalistic setting (Bernardi *et al.*, 1996; Osterheus *et al.* 1997; Serrador *et al.* 1999; Aoyagi *et al.* 2003; Mendonca *et al.*, 2009; Hautala *et al.*, 2010). Mendonca *et al.* (2009) found five minutes of treadmill walking increased low-to-high frequency ratio from 1.9 ± 0.4 at rest to 3.6 ± 0.8 post-walking in a group of healthy adults. Given that walking can reasonably be considered to be an activity frequently undertaken as part of a normal working day, often even in relatively sedentary occupations, this finding clearly has implications for the use of ambulatory monitoring of heart rate variability during the working day.

The results of a constant-routine protocol revealed heart rate variability, with a periodicity less than one hour, to be relatively independent of behavioural effects, including daily activity (Aoyagi *et al.* 2003). However, the study only assessed seven subjects and the type of activity included in the assessment of routine is

unclear. Bernardi *et al.* (1996) compared heart rate variability at rest with both rhythmic and spontaneous activities by investigating spectral parameters of heart rate variability in ten healthy male subjects over a total period of three hours. The resting condition involved participants remaining in a supine position for an hour, whilst the rhythmic activity involved alternating three minute cycles of rest with ten seconds of walking and stair climbing. The spontaneous activity, which was performed in no particular order, involved sitting, reading, walking and climbing stairs. The study revealed that, compared to at rest, power in the very low frequency band increased three to five fold during rhythmic or spontaneous activity and, contrary to most findings regarding exercise and heart rate variability, the total power increased from rest to rhythmic activity and further to spontaneous activity. Whilst there was no difference in either low frequency or high frequency power according to condition, there was a relative increase in low frequency power and a decrease in high frequency power. However, given the nature of the rest condition, it is possible that posture was, at least partly, responsible for the differences between conditions, rather than activity alone. In a similar investigation, Serrador *et al.* (1999) monitored the same number of subjects at rest and during light activity, but they underwent each condition on separate days, and the rest condition involved a sitting, rather than supine posture. The light activity comprised walking, typing and sorting through magazines. The results again revealed total power to be greater in the active condition compared to rest, although the difference failed to reach significance. A significant reduction in the ultra-low frequency power occurred from the active to resting condition, but there were no differences in the remaining parameters of heart rate variability, i.e. very low frequency, low frequency and high frequency according to activity. Even

though the study included fifteen minutes of walking, this was contained within the three hour 'active' period where the remainder of the activities were relatively sedentary and presumably all performed in a seated position.

Osterheus *et al.* (1997) used a field-based approach to investigate the influence of physical activity upon heart rate variability amongst a cohort of 106 hospital patients with coronary artery disease. The study involved twenty four hour ambulatory monitoring of patients, either undergoing bed rest or undertaking normal daily physical activity during the recording period, and a healthy control group. The authors found that all time domain measures of heart rate variability were significantly greater in both the active and control groups compared to the bed rest group. However, given the nature of bed rest, it seems reasonable to assume that this group were in the supine position for much of the duration of the recording, so the greater heart rate variability cannot be attributed to activity alone.

In what appears to be the first observational field based investigation of the association between physical activity and spectral parameters of heart rate variability, during every day free living Hautala *et al.* (2010) assessed 45 healthy subjects during waking hours over two consecutive days. Although limited detail is provided regarding the nature of the study days, participants were only advised to avoid vigorous exercise, with work and leisure time physical activity permitted. In addition to the observational approach, the correlational analysis undertaken should provide a useful insight into the extent to which everyday levels of activity

influence parameters of heart rate variability compared to studies which have experimentally manipulated activity levels and investigated differences between conditions. The results of the study revealed physical activity to demonstrate an inverse association with sample entropy, but only a non-significant trend toward an association with high frequency power and the low-to-high frequency ratio. In simple terms, sample entropy provides a measure of the degree of repeatability between epochs within time series data, so greater physical activity resulted in less irregularity in the data. However, the statistical analysis, which involved performing individual correlations for each participant along with a sign test, arguably failed to make full use of the available data. Alternative methods of statistical analysis, such as a within-persons correlation (Bland and Altman, 1995) can attend to the variation within-subjects, negating the need to perform multiple individual correlations.

In summary, the extent to which relatively moderate levels of activity influence heart rate variability is currently unclear. Therefore, the aim of the present study was to investigate whether levels of daily free living work time physical activity are associated with blood pressure and heart rate variability at the intra-individual level, and whether this relationship is altered by variations in concurrent psychosocial demand. The hypothesis were that: i) blood pressure would be positively associated with work-time physical activity; ii) the low-to-high frequency ratio of heart rate variability would be positively associated with work-time physical activity; iii) the strength of the association between physiological measures and physical activity would differ according to the degree of psychosocial demand present.

7.2. METHODS

The electrocardiogram and motility data used for this investigation was collected during two separate observational studies as outlined in chapter 3.

7.2.1 Data analysis

Study one: The electrocardiogram recording for each participant was divided into 30 minute epochs to coincide with the timing of ambulatory blood pressure measurements i.e. the period between the commencement of recording and the initial inflation of the blood pressure cuff, and then the period between all subsequent inflations. The relevant 30 minute segments of the recording were manually selected using CardioVisions software version 1.19.0 which provides the mean low and high frequency power (both in absolute terms, and in normalised units), and the low-to-high frequency ratio for each epoch. Motility data was downloaded from the Actiheart using the Actiheart software version 2.0 (CamNTEch, Cambridge). The data was exported into an Excel spreadsheet and then divided into the same 30 minute epochs as the electrocardiogram data to provide a mean activity count for each period. This yielded an average of 28 epochs worth of data for each participant.

Study Two: Continuous twenty four hour ambulatory assessment of a single male participant over twenty one days, provided a total of 504 hours' worth of concurrent data, and 150 hours of work time data. The 150 hours of work time data were reduced to 30 minute epochs. Additionally, the data obtained on day one of the study was reduced to epochs of a single minute for further analysis.

7.2.2. Statistical Analysis:

Study one: An analysis of covariance was performed to segment the variability into between and within-subject components. The variation in both blood pressure and heart rate variability was then obtained by calculating the square root of: (the sum of squares for activity) divided by (the sum of squares for activity + the residual sum of squares) (Bland & Altman, 1995).

Study two: Data from the single subject case study was investigated by means of spearman's correlations. All statistical calculations were computed using SPSS version 20.0 and the significance level was set at $p < 0.05$.

7.3. RESULTS

Study one

Table 7.1 presents activity levels and also physiological data according to the demands of the assessment day for ease of comparison. Activity levels were relatively low and did not differ according to assessment day. Heart rate and blood pressure and sympathetic dominance were all significantly greater on the more demanding day (Table 7.1).

Table 7.1 Mean daily levels, heart rate and blood pressure

	Less Demanding	More Demanding
Activity (movement counts)	39.39 ± 28.89	48.49 ± 25.74
Heart Rate (bpm)	72.9 ± 9.96	76.58 ± 13.36*
Systolic Blood Pressure	121.62 ± 6.89	126.37 ± 7.73*
Diastolic Blood Pressure	75.83 ± 5.18	78.60 ± 5.01*
LF power	74.40 ± 11.76	79.50 ± 8.83*
HF power	24.35 ± 11.05	19.85 ± 8.00*
LF/HF ratio	3.87 ± 2.08	4.72 ± 2.33*

Activity expressed in movement counts. Heart rate in beats per minute. LF power: low-frequency power in normalised units. HF power: high-frequency power in normalised units. LF/HF ratio: low-to-high frequency ratio. *denotes significant difference ($p < .05$)

When data was combined across both study days, activity was shown to demonstrate a strong positive association with heart rate ($r = .66$, $p < .05$), small to moderate positive associations with systolic blood pressure ($r = .25$, $p < .05$)

and diastolic blood pressure ($r = .27$, $p < .05$) and small associations with total power of heart rate variability ($r = 0.10$, $p < .05$) as shown in Table 6.2.

Table 7.2. Within-subjects associations between activity and HRV/BP.

	Less Demanding (p)	More Demanding (p)	Aggregated (p)
LF (ms)	0.17(.438)	0.00(.657)	0.03(.452)
LFnu	0.10(.356)	0.03(.424)	0.05(.700)
HF (ms)	-0.04(.234)	-0.09(.604)	-0.07(.349)
HFnu	-0.12(.235)	-0.03(.415)	-0.07(.632)
LF:HF	0.09(.386)	0.07(.656)	0.09(.046)*
Total Power (ms)	0.17(.032)*	0.08(.210)	0.10(.045)*
Heart Rate (bpm)	0.31(.003)**	0.73(.030)*	0.66(.016)*
SBP	0.38(.002)**	0.28(.002)**	0.25(.004)**
DBP	0.25(.000)**	0.32(.000)**	0.27(.000)**

* $p < 0.05$, ** $p < 0.01$ LF = low frequency power, HF = high frequency power. nu = normalised units, LFHF = low to high frequency ratio, SBP = systolic blood

Systolic blood pressure demonstrated a marginally stronger correlation with activity on the less demanding day ($r = .38$) than on the more demanding day ($r = .28$), whilst the opposite was the case for diastolic blood pressure ($r = .25$ and $r = .32$). Heart rate demonstrated a greater association with activity on the more demanding day ($r = .73$) than the less demanding day ($r = .31$). The association between total power and physical activity remained significant on the less demanding day only, although the strength of the association was weak ($r = 0.17$).

There was no association between any of the remaining variables and physical activity on either day.

Study Two

Table 7.3 presents the mean work-time activity, heart rate and heart rate variability data from the single-subject case study. There was substantial variation in activity levels, heart rate and all measures of heart rate variability over the duration of the 21 study days.

Table 7.3 Mean work-time data (single participant)

Measure	Mean	SD +/-	%CV
Activity	56.14	34.59	61.61
Heart Rate	68.40	16.55	24.20
Ave IBI	933.56	12.52	13.02
Min IBI	753.40	112.61	14.95
Max IBI	1114.57	134.09	12.03
SD	82.21	18.72	22.77
RMSSD	69.48	25.93	37.32
LF (ms)	2699.82	1672.93	61.96
HF (ms)	1722.37	1611.42	93.56
LF/HF	2.95	0.82	27.80

Ave IBI: Average interbeat interval, Min IBI: Minimum Interbeat interval, Max IBI: Maximum interbeat interval, SD: standard deviation of the RR interval, RMSSD: Root mean square of successive differences, LF: Low frequency power (milliseconds), HF: High frequency power (milliseconds), LF/HF: low-to-high frequency ratio.

Associations between activity and physiological measures are presented in Table 7.4. Activity counts were significantly related with all physiological measures. Activity was moderately and positively correlated with heart rate ($r=.495$). The average and minimum interbeat intervals demonstrated moderate negative associations with activity ($r=-.493$ and $r=-.520$ respectively), whilst the maximum interbeat interval was only weakly associated with activity ($r=-.270$). Low frequency power, and the low-to-high frequency ratio demonstrated moderate positive associations ($r=.227$ and $r=.266$ respectively) whilst high frequency power demonstrate a very weak negative association with activity ($r=-.057$).

Table 7.4. Associations between work time activity and heart rate variability (single participant)

	Activity
Heart Rate	.495*
Average Interbeat Interval	-.493*
Minimum Interbeat Interval	-.520*
Maximum Interbeat Interval	-.270*
Standard Deviation of NN interval	.243*
Root Mean Square of Successive Differences	-.116*
Low Frequency Power (ms)	.227*
High Frequency Power (ms)	-.057*
Low-to-high frequency power	.266*

Spearman's correlations using day-time data from 15 working days with epochs of one minute. * denotes significant difference ($p<0.05$).

Associations between activity and heart rate variability, according to epoch duration are presented in Table 7.5. When data analysis was performed using epochs of 30 minutes, significant correlations were found to exist between activity and all of the time domain indices of heart rate variability, but not for any of the frequency parameters. However, when using single minute epochs, all measures were found to be significantly associated with physical activity, although the magnitude of correlations is similar between different durations.

Table 7.5. Relationships between HRV and activity according to epoch

	30 minute	1 minute
Heart Rate	.635**	.600***
Ave IBI	-.617**	-.603***
Min IBI	-.680**	-.584***
Max IBI	-.549*	-.427***
SD	.119	.191***
RMSSD	-.186	-.246***
LF	.214	.316***
HF	-.368	-.264***
LFHF	.438	.489***

Spearman's correlations using day-time data from a single study day *p<0.05, **p<0.01, ***p<0.001

Both physical activity and spectral parameters of heart rate variability demonstrated high levels of variability from one minute to the next (Figure 7.1). This may explain why activity and heart rate variability were found to demonstrate

an association when using epochs of a single minute, but not when longer epochs of 30 minutes were used.

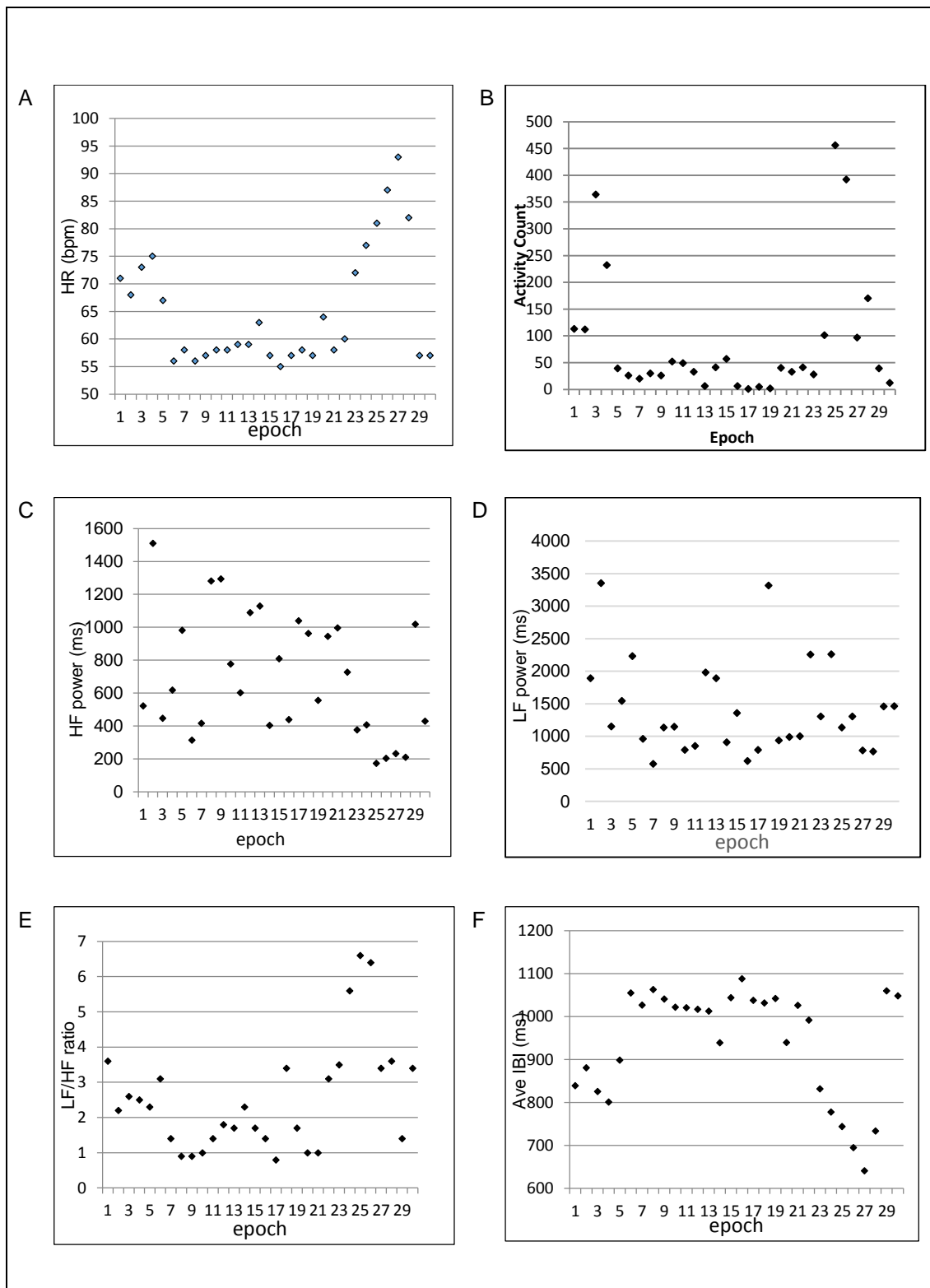


Figure 7.1. Minute by minute data from a single 30 minute epoch. A: Heart Rate (bpm), B: Activity (Movement Counts), C: HF power (ms), D: LF power (ms), E: LF/HF ratio, F: Average Interbeat Interval

7.4. DISCUSSION

The aim of this study was to investigate whether moderate levels of work-time physical activity are associated with ambulatory blood pressure and heart rate variability. It was hypothesised that: i) blood pressure would be positively associated with work-time physical activity; ii) the low-to-high frequency ratio of heart rate variability would be positively associated with work-time physical activity; iii) the strength of association between physiological measures and physical activity would differ between the “less demanding” and the “more demanding” days. As both systolic and diastolic blood pressures were found to demonstrate positive associations with physical activity the results support the first hypothesis. The second hypothesis, that various parameters of heart rate variability would demonstrate associations with activity, has been found to be partially supported; results differed between the group study and the case study. As there were no consistent differences in the relationships between activity and either blood pressure or heart rate variability according to the magnitude of acute demand the results do not support hypothesis iii.

Although support was found for the first hypothesis, the association between blood pressure and heart rate variability was not particularly strong, with activity only accounting for between 7 and 14 percent of the variance in blood pressure. In other words, the majority of variation in blood pressure cannot be explained by variation in activity levels. This can possibly be explained by the relatively low levels of physical activity found within the present study. As anticipated, given the sedentary nature of the participant’s occupations, the intensity of physical activity

during work time was relatively low, with average movement counts being roughly equivalent to those previously shown to occur whilst playing cards (Spierer *et al.*, 2011). Although the present investigation did not control for posture, and cannot rule out the possibility that variation in posture may have accounted for variation in blood pressure, it is unlikely that postural changes would occur without changes in activity. Therefore, variations in blood pressure during working hours may have been largely related to psychosocial factors. Certainly, the results presented in Chapter 4 demonstrated that blood pressure was significantly greater on the day containing a higher degree of work-related demand, which would appear to support this argument. In practical terms therefore, the fact that ambulatory blood pressure appears to be largely independent of physical activity suggests that activity levels do not present a significant threat to the internal validity of ambulatory monitoring in the naturalistic setting of the workplace.

Turning to heart rate variability, the results of the present study highlight differences in the extent to which time domain and spectral parameters are influenced by physical activity. The analysis of electrocardiogram data obtained from the single-subject study found all measures of interbeat interval to be associated with concurrent physical activity. This is in accordance with previous findings (Osterheus *et al.*, 1997) and suggests that time domain measures of heart rate variability are influenced by moderate levels of activity, such as might occur during every day work in higher education employees. Therefore, in order to interpret time domain heart rate variability in response to psychosocial stressors, consideration must be given to the level of physical activity that occurs during the recording period.

The extent to which spectral parameters of heart rate variability are influenced by physical activity requires more careful interpretation. The results from the group study revealed the total power of heart rate variability to demonstrate an association with physical activity, albeit a small one. However, there was only a non-significant trend for activity to be associated with low frequency power, high frequency power, and the low-to-high frequency ratio. This suggests that any influence of physical activity upon heart rate variability occurs within frequencies out with the low and high frequency bands. This is in keeping with much of the existing literature which has found activity to alter the very and ultra-low frequency parameters of heart rate variability (Bernardi *et al.*, 1996; Serrador *et al.*, 1999). However, the presence of a non-significant trend towards association for spectral parameters of heart rate variability and physical activity mirrors the findings of Hautala *et al.* (2010) who performed their analysis on a similar number of epochs, obtained from 40 participants. The present analysis extends these findings by making greater use of the available data by employing within-persons correlations (Bland and Altman, 1995). Nevertheless, despite both of these studies detecting a trend towards statistical significance, the size of the effect is very small. Therefore, the results of the group study suggests that spectral parameters of ambulatory heart rate variability, within the low and high frequency ranges, are relatively immune from the effects of work-related physical activity.

The analysis of the data from the single-subject design, on the other hand, revealed all parameters of heart rate variability, including low and high frequency power and the low-to-high frequency ratio to be associated with physical activity. The direction of these associations indicates that higher levels of activity increase

sympathetic dominance of the autonomic nervous system, which is in accordance with earlier findings relating to exercise (Mendonca *et al.*, 2009). There are a number of possible explanations as to why significant associations were found between activity and spectral parameters of heart rate variability in the case-study but not the group study. Firstly, given the intra-individuality of physiological responses, specifically in terms of cardiovascular reactivity (Cacioppo *et al.*, 1998), it is not beyond the realms of possibility that the single-subject demonstrated a genuinely different response than the subjects within the group study. Indeed, returning once more to the recent investigation by Hautala *et al.*, (2010), individual differences have previously been shown to exist in the relationship between activity and heart rate variability. The reasons why this may be the case are unclear and would certainly be worthy of further investigation. Cardiovascular fitness is a likely moderator of the relationship between activity and heart rate variability as previous studies have reported that heart rate variability is significantly influenced by aerobic conditioning (Meersman, 1993; Levy *et al.*, 1998; Aubert *et al.*, 2003).

An alternative explanation for the discrepant results according to the data being analysed may lie in the fact that there were some minor methodological differences in the data collection. For example, different equipment was used to record electrocardiogram data, i.e. Holter versus Actiheart. It is however, unlikely that that this had any effect on the results, as the Actiheart has previously been shown not to demonstrate any marked differences from Holter monitoring (Kristiansen *et al.*, 2011). Although the 2 lead monitoring of electrocardiogram by the Actiheart is potentially prone to greater error than the 5 lead Holter monitoring,

this is counterbalanced by the signal being less susceptible to interference during upper body movement. Different methods were also used in the analysis of the electrocardiogram data, in terms of the epoch length used to determine heart rate variability: 30 minutes for the group study and 1 minute for the single participant case study. Although the Task Force (Task Force, 1996) recommended a minimum recording duration of 5 minutes, this appears to be predicated upon the fact that the very low frequency component of heart rate variability assessed from recordings of less than 5 minutes has been deemed inappropriate. Therefore, the 5 minute duration was recommended primarily to promote standardisation, which is sensible, but does come with the caveat that certain research questions may be better addressed by recordings of differing duration. Indeed, the Task Force also stated that recordings of approximately 1 minute are needed to assess the high frequency components of heart rate variability while approximately 2 minutes are needed to address the low frequency component. The Actiheart software can provide data in epochs of 15 seconds, 30 seconds, 1 minute or 5 minutes. The one minute epoch analysis for low frequency components actually uses a two minute data period centred on the minute in question which is then weighted by a Hanning window function before the Fourier transform. This effectively means that whilst the central minute controls the majority of the output from that period, a two minute window is used to provide a long enough period of data for the low frequency components to be effectively measured.

The method of data analysis is therefore an important consideration. Short-term measures of heart rate variability are known to rapidly return to baseline following transient perturbations from stressors like mild exercise (Task Force, 1996) and

the substantial minute-to-minute variation in activity, heart rate and heart rate variability in the present study demonstrates the speed with which the autonomic nervous system reacts to physical stress (Ulrich-Lai & Herman, 2009). This may explain why the case study revealed different results according to the epoch duration selected. When a segment of the case study data was analysed using a 30 minute epoch the results mirrored those obtained in the group study, i.e. there was no association between activity and heart rate variability. However, when with an epoch of one minute was used, activity counts were significantly associated with all measures of heart rate variability. Therefore, it is entirely plausible that obtaining mean values over longer epochs may conceal the true relationship between physical activity and heart rate variability, which may explain why previous investigations have failed to find a statistically significant association between physical activity and low or high frequency heart rate variability. Although worthy of further investigation it is, again, worth reiterating the distinction between statistical significance and practical significance when interpreting the results of the present study. The fact that, under specific analyses, activity was significantly associated with measures of heart rate variability does not necessarily mean that activity poses a threat to the internal validity of ambulatory monitoring. In fact when attention is turned to the size of effects it becomes evident that, whilst statistically significant, activity shares less than a quarter of its variance with the low-to-high frequency ratio.

Perhaps the greatest methodological challenge associated with ambulatory monitoring as a research tool is one of maximising ecological validity without excessively compromising internal validity (Fahrenberg *et al.*, 1996). Although, it

is not always possible, nor necessarily desirable, to eliminate extraneous influences upon the variable of interest during assessment in the field, attending to a greater number of independent variables can potentially enhance the internal validity of the data, aiding interpretation. The present findings suggest that while there may be some benefit to be gained from attending to physical activity during ambulatory assessment of heart rate variability, the consequences of not doing so appear relatively minor. However, to illustrate the complexity of interpreting data obtained under free-living conditions, it cannot be assumed that activity levels were being observed against a stable environmental backdrop in the present study. Indeed, given the nature of the assessment period, i.e. during working hours, some thought should be given to what an increased level of work time activity actually represents, and how it may interact with the psychosocial work environment. That is to say that the reason for increased activity is potentially significant. Where increased activity is a manifestation of both the physical and psychosocial environments within which the assessment occurs, as could occur in the delivery of a particularly challenging presentation or lecture, it becomes impossible to attribute variations in physiological function to either activity or psychosocial demand alone. It has previously been demonstrated that delivering a lecture to 200 students causes a significant decrease in the high frequency component of heart rate variability and an increase in the low-to-high frequency ratio (Filaire *et al.*, 2010). Therefore, if activity is merely assumed to represent a confounding variable then the relationship between the psychosocial stress of the lecture and heart rate variability could be missed.

Although possible, in theory, to design a field-based study in such a way that the potential effect of variables other than activity upon ambulatory heart rate variability are minimised, this would most likely involve a degree of manipulation likely to cause the environment to be perceived as being less than natural: and therein lies the dichotomy of ambulatory research. It is therefore important to apply a judgement as to whether potential confounding variables actually represent a genuine threat to the validity of the study or whether they might be linked to the variable of interest. Several authors have argued that ambulatory monitoring of heart rate variability should include a concurrent assessment of activity, based upon the influence exerted upon very-low, ultra-low, repeatability and vagal measures of heart rate variability (Bernardi *et al.*, 1996; Grossman *et al.*, 2004; Serrador *et al.*, 1999; Hautala *et al.*, 2010). The findings of the present study suggest that levels of physical activity likely to be encountered in the performance of relatively sedentary occupations presents little threat to the internal validity of ambulatory assessment of heart rate variability in the low and high frequency range, or to ambulatory blood pressure. Additionally, given the possibility that variations in activity amongst certain cohorts of employees may reflect exposure to psychosocial demand, then controlling for activity may present as many problems as it solves.

Limitations:

Some of the data analysis reported within this chapter was performed on the data obtained from a single participant. As such the analysis relied upon

psuedoreplication and the results should not be extrapolated to a more general population.

Contribution of the present results to the thesis.

- Evidence to suggest that ambulatory monitoring of worktime blood pressure, heart rate and time domain parameters of heart rate variability may be influenced by concurrent activity levels in higher education employees.
- Spectral parameters of heart rate variability appear to be relatively free from the influence of worktime activity levels, although shortening the length of recording epoch may increase the effect of activity.
- The strength of association between activity and physiological responses does not appear to be influenced by perceived psychosocial hazard.

CHAPTER 8. The cortisol awakening response: issues of compliance and sleep-related factors – is heart rate variability the solution?

8.1 INTRODUCTION

Although the anticipation hypothesis asserts that the response reflects the perceived demands to be faced in the day ahead (Clow *et al.*, 2010), the possibility that other factors contribute to the response cannot be ignored. Unsurprisingly, given the nature of the response, much attention has been given to the possibility that sleep-related factors are involved in the response, albeit results are, at present, inconsistent (Garde, 2012). The relationship between sleep and the hypothalamic-pituitary adrenal axis is complex and bidirectional (Balbo *et al.*, 2010). Similarly, sleep and stress are also believed to demonstrate a bidirectional relationship (Khan *et al.*, 2013), which may begin to explain the influence of psychosocial stress upon the cortisol awakening response. Awakening time is perhaps the most widely investigated sleep-related covariate, yet evidence relating to the influence of awakening time upon the cortisol awakening response is largely contradictory. Several authors have reported an absence of association between time of awakening and the cortisol awakening response at the between subject level (Preussner *et al.*, 1997; Kunz-Ebrecht *et al.*, 2004; Liberzon *et al.*, 2008), whilst others found awakening time to be negatively associated with measures of awakening cortisol (Edwards *et al.*, 2001; Kudielka & Kirschbaum, 2003; Thorn *et al.*, 2006; Rotenburg & McGrath, 2014). As noted by Williams *et al.* (2005) it is difficult to disentangle the effects of many psychosocial factors and the effects of awakening time using a between-subject approach, as people experiencing stress are more likely to wake earlier. Using a within-subjects design, Hucklebridge *et al.* (2002) found no difference in the cortisol awakening response between awakening at normal time or four hours

earlier. A more recent within-subject investigation of the effect of awakening time in a cohort of shift working nurses found early awakening to be associated with a greater cortisol response than later awakening and nightshift awakening (Federenko *et al.*, 2004). The opposite effect was observed by Dahlgren *et al.* (2009), who assessed a cohort of office workers over four consecutive weeks and found later awakening to be associated with higher levels of cortisol fifteen minutes after awakening. Similarly, results from a single-subject case study found later awakening to be associated with higher levels of cortisol in the awakening sample (Stalder *et al.*, 2009). However, a methodological limitation of all of these studies is a failure to adequately control for both time of awakening and sampling time. Furthermore, many of these studies have incorporated substantial variation in times of awakening, for instance comparing different times of awakening in shift workers, which increases the potential for awakening time to be related to psychosocial factors. The extent to which more modest variations in awakening times are associated with the cortisol awakening response is less clear.

The possible influence of sleep duration upon the cortisol awakening response is another factor which has thrown up conflicting results. Several studies have reported there to be no association between sleep duration and awakening cortisol (Zhang *et al.*, 2011; Hansen *et al.*, 2012; Stalder *et al.*, 2010), whilst both Wust *et al.* (2000b) and Kumari *et al.* (2009) found duration of sleep to be negatively associated with the response. Vargas and Lopez-Duran (2014) found sleep duration to be positively associated with the area under the awakening cortisol curve. Similarly discrepant findings exist regarding sleep quality: both Hucklebridge *et al.* (2002) and Dettenborn *et al.* (2007) found that disturbed sleep

does not influence awakening cortisol, but a recent study reported a strong association between the same variables (Powell *et al.*, 2012). Similarly, Backhaus *et al.* (2004) found subjective sleep awakenings and sleep quality to be negatively associated with cortisol in the awakening sample and Lasikiewicz *et al.* (2008) reported sleep quality to be associated with a blunted cortisol response to awakening.

An alternative sleep-related parameter that might exert an influence upon the cortisol awakening response is nocturnal movement. Movement during sleep is an entirely normal occurrence, and there is a strong relationship between movement and sleep stages (Muzet *et al.*, 1972; Jansen & Shankar, 1993; Shimohira *et al.*, 2008) with sleep body movement predominantly occurring during rapid eye movement sleep (Gori *et al.*, 2004). Although dynamics of awakening cortisol do not appear to have been investigated in respect to the stage of sleep from which awakening occurs, there is evidence that awakening from rapid eye movement sleep results in greater negative emotions (Wagner *et al.*, 2002; McNamara *et al.*, 2010) and enhanced reactivity to negative stimuli when compared with waking from other sleep stages (Lara-Carrasco *et al.*, 2009). It seems plausible, therefore, that differing levels of movement prior to awakening may be indicative of waking from different stages of sleep which could exert an influence upon the cortisol response to awakening.

Additionally, given the significant implications of non-compliance with the sampling protocol, the cortisol awakening response is unlikely to be appealing

outwith the research environment. If an alternative, more easily assessed measure of the physiological stress response to awakening could be identified then it may be more successfully adopted in real world assessment. The autonomic nervous system and the hypothalamic-pituitary-adrenal axis are integrated at various levels and, as a result, are often investigated simultaneously (Licht *et al.*, 2010; Stalder *et al.* 2011). The cortisol awakening response is believed to be fine-tuned by neural input to the adrenal gland (Clow *et al.*, 2010) and there is evidence to suggest that cortisol secretion is influenced by basal sympathetic activity of the autonomic nervous system (Kizildere *et al.*, 2003; Young *et al.*, 2005). Both systems follow similar circadian rhythms and it has been shown that awakening is associated with enhanced sympathetic dominance of the autonomic nervous system: i.e. reduced high-frequency power, increased low-frequency power and low-to-high frequency ratio (Huikuri *et al.*, 1994).

To date there have been relatively few attempts to investigate interactions between heart rate dynamics during the awakening period and the cortisol awakening response. Stalder *et al.* (2011) performed a simultaneous assessment of salivary free cortisol and heart rate variability over the awakening period, but failed to find any association between the two variables. However, Izawa *et al.* (2010) reported sympathetic activity in the 30 minutes preceding and following awakening to be associated with the area under the cortisol curve with respect to both increase and ground. The possible relationship between these two variables warrants further investigation, as the assessment of heart rate variability over the awakening period could provide a more practical, user friendly assessment tool.

As a result, a further aim of the present study was to investigate simultaneous heart rate variability and salivary free cortisol over the awakening period.

In summary, the aim of this chapter is to investigate the influence of non-psychosocial factors upon the cortisol awakening response. Specifically whether sleep related factors influence the cortisol awakening response and whether an alternative to the cortisol awakening response may be found in measuring heart rate variability over the awakening period. It was hypothesised that: i) heart rate variability over the awakening period would demonstrate an association with the cortisol awakening response; ii) nocturnal movement would be associated with the cortisol awakening response; iii) awakening time would influence the cortisol awakening response and; iv) salivary cortisol would increase over the awakening period on all measurement occasions.

8.2. METHODS

All data used in the present investigation was collected during the single-subject case study. Details of the participant are provided in section 3.2.2 and a description of the experimental protocol used to collect data is provided in section 3.4.5.

Determination of sleep, awakening times and sampling times:

Onset of sleep was deemed to occur at the point where ten minutes of consecutive activity counts of zero were recorded (Izawa *et al.*, 2010).

8.4 RESULTS

Table 8.1 presents mean pre and post awakening values of activity, heart rate and heart rate variability. Significant increases were observed over the awakening period for activity ($Z=-3.73$, $p<.001$, $\bar{X}_+ = 11.39$, $\bar{X}_- = 2.5$), heart rate ($Z=-2.28$, $p=.023$, $\bar{X}_+ = 12.77$, $\bar{X}_- =6.29$) and the low-to-high frequency ratio ($Z=-.243$, $p=.015$, $\bar{X}_+ = 12.14$, $\bar{X}_- =6.67$). The average inter beat interval ($Z=-2.28$, $p=.023$, $\bar{X}_+ = 5.50$, $\bar{X}_- = 13.83$) and root mean square of successive differences ($Z= 3.50$, $p<.001$, $\bar{X}_+ = 3.67$, $\bar{X}_- =-8.04$) decreased from pre to post awakening, whilst neither low-frequency power ($Z=-1.49$, $p=.881$, $\bar{X}_+ = 10.90$, $\bar{X}_- =10.10$) or high frequency power ($Z=-1.79$, $p=.073$, $\bar{X}_+=9.50$, $\bar{X}_- = 10.93$) changed significantly from pre to post awakening.

Table 8.1. Mean values for activity, heart rate and heart rate variability over the pre and post awakening periods for all 21 study days.

	Pre-awakening	Post-awakening
Activity	0.45 ± 0.42	3.27 ± 2.65 *
Heart Rate	51.07 ± 3.30	55.23 ± 5.59 *
Ave_IBI	1180.45 ± 57.4	1113.11 ± 93.60 *
SDNN	116.85 ± 34.0	111.63 ± 22.34
RMSSD	118.00 ± 41.62	100.72 ± 30.38 *
LF (ms)	2968.73 ± 634.97	3151.34 ± 1205.93
HF (ms)	3268.19 ± 1548.68	2743.57 ± 1116.72
LFHF	1.15 ± 0.45	1.68 ± 0.89 *

Activity: movement counts arbitrary units, Heart Rate: bpm, Ave_IBI: Average interbeat interval, SD: standard deviation of the normal RR interval, RMSSD: Root mean square of successive differences, LF: Low frequency power, HF: High frequency power. LFHF: ratio between low and high frequency power, Pre-awakening: 60 minutes prior to awakening, Post-awakening: 60 minutes following awakening.

All awakening times for the duration of the study are shown in Figure 7.1. Awakening times ranged from 05:48 to 07:46 hours, with each weekend containing at least one day on which the awakening time was later than occurred on all fifteen weekdays.

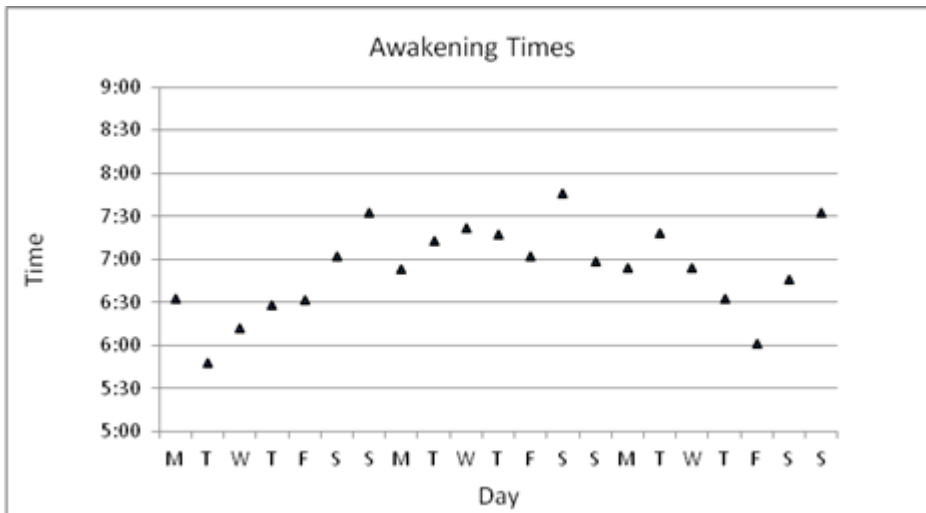


Figure 8.1. Awakening times for all 21 study days.

Associations between sleep-related parameters and the cortisol awakening response over the entire study are presented in Table 8.3. Awakening time demonstrated a moderate association with the area under the curve with respect to increase ($r = .488, p < .05$), but not with any other parameters of the cortisol awakening response. Nocturnal movement over the entire period of sleep did not demonstrate any associations with the cortisol response to awakening. Movement over the 60 minute period immediately prior to awakening was found to be moderately and positively associated with both the awakening sample ($r = .550, p < .05$) and with the area under the curve with respect to ground ($r = .536, p < .05$), but not the increase over the awakening period ($r = .238, p > .05$). There were no associations between post-awakening activity and the cortisol awakening response.

Table 8.2. Associations between sleep-related variables and salivary free cortisol over the awakening period.

	Awakening Sample	AUC _g	AUC _i
Awakening time (all days)	-.172	.118	.488*
Awakening time (weekdays)	-.234	.106	.479
Sleep duration	.109	.076	.206
Movement (sleep)	-.086	.003	.225
Movement (pre-awakening)	.550*	.536*	.238
Movement (post-awakening)	.062	.066	-.047

AUC_g: Area under the cortisol curve with respect to ground, AUC_i: area under the cortisol curve with respect to increase.

Associations between heart rate variability and the cortisol awakening response are presented in Table 8.4. High-frequency power of heart rate variability over the pre-awakening period demonstrated a positive association with the area under the curve both with respect to ground ($r = .645$, $p < .01$) and zero ($r = .660$, $p < .01$). There were no other associations between heart rate variability and the cortisol awakening response.

Table 8.3. Partial correlations between heart rate variability and the cortisol awakening response over the pre and post awakening period a).

	Awakening	AUC(g)	AUC(i)
<i>Pre-awakening</i>			
Ave IBI	-.341	.060	.214
SDNN	-.025	.154	.187
RMSSD	-.005	.150	.174
LF (ms)	.030	-.351	.398
HF (ms)	.339	.645*	.660*
LFHF	-.126	-.276	-.272
<i>Post-awakening</i>			
Ave IBI	-.216	-.359	-.360
SDNN	-.016	-.137	-.193
RMSSD	-.006	-.160	-.243
LF (ms)	-.052	-.145	-.176
HF (ms)	-.021	-.185	-.257
LFHF	-.339	.023	.287

a) Adjusted for awakening time. Ave IBI: average interbeat interval, SDNN: standard deviation of normal to normal intervals, RMSSD: root mean square of successive differences, LF: low-frequency power (milliseconds), HF: high-frequency power (milliseconds), LFHF: low-to-high frequency ratio, AUC(g): area under the cortisol curve with respect to ground, AUC(i): area under the cortisol curve with respect to the increase. * denotes significant correlation ($p < .05$)

8.4 DISCUSSION

The aim of the present investigation was to determine whether compliant cortisol awakening responses were associated with heart rate variability, or with sleep-related factors over the awakening period at the within-subject level. An additional

aim was to investigate whether there is evidence to suggest non-normal responses are genuine and not merely artefactual. It was hypothesised that: i) heart rate variability over the awakening period would demonstrate an association with the cortisol awakening response; ii) nocturnal movement would be associated with the cortisol awakening response; iii) awakening time would influence the cortisol awakening response and; iv) salivary cortisol would increase over the awakening period on all measurement occasions. As vagal activity over the period immediately prior to awakening was associated with measures of the cortisol awakening response the present results provide support for hypothesis i. Additionally, both awakening time and nocturnal movement demonstrated associations with the cortisol awakening response providing support for both hypotheses ii and iii. There was also a clear response to awakening on all assessment days providing support for hypothesis iv.

The finding that high frequency heart rate variability in the latter stages of sleep was positively associated with the cortisol awakening response suggests that the cortisol awakening response is influenced by the balance of the autonomic nervous system. The results of a recent between-subject investigation found sympathetic activity over the awakening period to be negatively associated with awakening cortisol, but vagal activity was unrelated to the response (Izawa *et al.*, 2010). These two findings are not necessarily contradictory and there exists a degree of synchronicity between them; both suggest that greater sympathetic dominance of the autonomic nervous system is associated with a more pronounced cortisol awakening response. Although the adrenal gland is known to be fine-tuned by sympathetic activity (Stalder *et al.*, 2011), and sensitivity to

adrenocorticotrophic hormone appears to be mediated by sympathetic activity (Clow *et al.*, 2010) the potential involvement of vagal activity in the response is less clear. Another recent between-subjects investigation (Stalder *et al.*, 2011) found there to be no association between heart rate variability and the cortisol awakening response. Stalder *et al.*, (2011) suggested that between-individual variation in basal hypothalamic-pituitary-adrenal activation may have influenced their findings, and the present results provide preliminary support for this contention. As no previous attempts have been made to investigate heart rate variability and the cortisol awakening response simultaneously at the within-individual level, the present results represent an important contribution to the literature. Whilst further investigation is required to determine whether these results can be replicated they provide preliminary evidence to suggest that parameters of heart rate variability over the awakening period are implicated in the cortisol awakening response.

The involvement of pre-awakening physiological influences on the cortisol awakening response could be considered to cast some doubt over the validity of the anticipation hypothesis. However, it has previously been demonstrated that nocturnal heart rate variability is affected by experimentally induced anticipatory stress (Hall *et al.*, 2004). Therefore, although the anticipation hypothesis may not adequately explain the phenomenon of the cortisol awakening response, as it generally assumes that the anticipation occurs at the time that consciousness is regained (Fries *et al.*, 2009), this does not necessarily rule out the importance of anticipation in the response. The possible involvement of nocturnal anticipation

in the cortisol awakening response does however, raise a methodological question regarding the best time to assess anticipation.

Turning to the other pre-awakening factor, nocturnal activity, there was a lack of association between the cortisol awakening response and activity over the entire sleep period. However, the present study appears to be the first to identify a relationship between movement over the period immediately prior to awakening and the cortisol response to awakening, with greater movement being associated with higher levels of cortisol upon awakening. Given that activity and vagal activity over the pre-awakening period demonstrated opposing associations with the cortisol awakening response, it is possible that activity levels contributed to the relationship between heart rate variability and the cortisol awakening response. There are a couple of possible explanations for the association between activity and the cortisol awakening response. Firstly, it could be that activity is indicative of the participant actually being awake prior to the reported awakening time; however visual inspection of the electrocardiogram data over this time frame would suggest this is not the case, as the pattern of heart rate and heart rate variability do not indicate awakening, i.e. there is no sudden increase in heart rate or sustained activity. An alternative explanation draws upon the physiological changes known to occur during different stages of sleep. As activity levels are known to be greater during rapid eye movement sleep (Gori *et al.*, 2004), it may be that in the present study higher levels of activity prior to awakening serve as an indication of awakening from rapid eye movement sleep. It has previously been shown that awakening from rapid eye movement sleep is associated with negative emotions (Wagner *et al.*, 2002; McNamara *et al.*, 2010) and enhanced

reactivity to negative stimuli when compared with waking from non-rapid eye movement sleep (Lara-Carrasco *et al.*, 2009). Therefore, if activity levels in the latter phase of sleep are accepted as being indicative of the stage of sleep prior to awakening, the association between activity and the cortisol awakening response in the present study would be in keeping with enhanced reactivity following awakening from rapid eye movement sleep. Certainly, the fact that salivary free cortisol in the awakening sample was not found to be associated with nocturnal activity in the latter phase of sleep suggests that the mechanism underlying this relationship is more likely to be related to post-awakening rather than pre-awakening processes.

The relationship between the cortisol awakening response and stage of sleep prior to awakening does not appear to have previously been investigated, presumably due to the somewhat prohibitive necessity of using a sleep laboratory. Although Wilhelm *et al.* (2007) did investigate the cortisol awakening response in a sleep laboratory, they were unable to consider the influence of sleep stage prior to awakening as an insufficient number of subjects awoke from rapid eye movement sleep. However, the stage of sleep prior to awakening has been found to be one of the most critical factors affecting sleep inertia (Tassi & Muzet, 2000; Elder *et al.*, 2013). The cortisol awakening response appears to be heavily implicated in the process of sleep inertia, which has been described as “the transitional state of lowered arousal occurring immediately after awakening from sleep” (Tassi & Muzet, 2000, p.341). For instance, although sleep inertia can, on occasion, last for several hours, it rarely exceeds 30 minutes (Tassi & Muzet, 2000), which coincides with the cortisol awakening response. Similarly,

experimental dawn stimulation has been found to improve psychological markers of sleep inertia (Thompson *et al.*, 2014) and also to increase the cortisol awakening response (Thorn *et al.*, 2004). Therefore, given the apparent commonality between sleep inertia and the cortisol awakening response, and the fact that sleep stage prior to awakening influences sleep inertia, it seems entirely plausible that stage of sleep prior to awakening could similarly influence the cortisol awakening response. It certainly seems worth further investigation, as does the possibility that nocturnal activity may be capable of providing a rudimentary means of identifying stages of sleep in the field.

Awakening time was found to be positively associated with the increase in cortisol over the awakening period, so that later awakening elicited a more pronounced response than earlier awakening. The direction of this association is the opposite of that observed by the majority of studies reporting upon the effect of awakening time upon the cortisol awakening response (Edwards *et al.*, 2012; Kudielka & Kirschbaum, 2003; Federenko *et al.*, 2004; Thorn *et al.*, 2006; Rotenberg & McGrath, 2014). However, the results of the present study are broadly in agreement with those obtained during a similar single-subject case study (Stalder *et al.*, 2009), in so far as salivary free cortisol demonstrated a positive association with awakening time. Although different parameters of the cortisol awakening response were implicated in each case study, taken together the results indicate that at the within-subject level time later awakening is associated with a more pronounced cortisol awakening response. There are various possible reasons for the consistency between findings obtained using a single subject approach and their disagreement with findings from group studies. Firstly, as none of the group

studies appear to have controlled for adherence to the sampling protocol, it is possible that differences in the cortisol awakening response according to time of awakening may reflect different levels of adherence. Although Stalder *et al.* (2009) did not use an objective measure of adherence they argue that the use of a participant-researcher design should be sufficient to ensure adherence to the sampling protocol. Alternatively, it is possible that both participants in the case studies simply demonstrate a similar physiological response to awakening, which differs from the average response in a group, which could potentially be accounted for by individual chronotype (Griefhan & Robens, 2008). A further explanation may lie in the difficulty of separating the effects of psychosocial factors and awakening time upon the cortisol awakening response using a between-subjects approach (Williams *et al.*, 2005).

Whilst the present study found relatively little variation between the earliest and latest awakening times, the latest awakenings occurred on weekend days, which could imply that the association between awakening time and the cortisol awakening response results from variation in the acute psychosocial environment. Certainly, when weekdays alone were included in the analysis, awakening time was no longer associated with any measures of salivary free cortisol over the awakening period. This lack of association between awakening and salivary cortisol over the awakening period on workdays is in itself not all that surprising, given the participant followed a structured routine during the week which involved arriving at work at the same time every day. Nevertheless, this has potentially significant implications for study design, suggesting that merely including awakening time as a covariate may not always be the most appropriate approach. Within the field of occupational health research, variation in awakening

times may well be indicative of acute work-related factors, i.e. different shift patterns, or anticipated workload, which are meaningful in their own right.

On a final methodological note, although the finding that cortisol demonstrated a clear increase on every sampling occasion cannot be interpreted as definitive evidence that non-normal or negative responses are artefactual in origin, it provides further evidence to suggest that healthy adults demonstrate an increase in salivary free cortisol over the awakening period. This adds to previous findings from both laboratory (Wilhelm *et al.*, 2007) and field studies (Stalder *et al.*, 2011). Additionally, although the mini-review of the recent literature found that incidence of non-normal samples were reported, the studies had failed to adequately control for compliance. Indeed the review highlighted the continuing lack of validity within research into the cortisol awakening response.

In conclusion, the present study provides two main contributions to the literature relating to the cortisol awakening response. Firstly, the lack of any negative responses when sampling adherence is strictly controlled suggests that such an occurrence may well be an artefact resulting from non-adherence. Secondly, heart rate variability in the pre-awakening period is associated with the cortisol awakening response at the within-individual level, although the extent to which this is influenced by movement is unclear. As a result it is strongly recommended that future studies of the cortisol awakening response incorporate a means of controlling for compliance with the reporting of both awakening and sampling times. Moreover, as such recommendations have been made previously, and

remain largely ignored, future studies should, at a minimum, include sufficient detail to ascertain whether any negative awakening responses were observed and, if so, what, if any measures were taken to attend to this as possible sampling error.

Limitations

The results of the present study were obtained from a single-subject case study, so cannot be assumed to extrapolate to a wider population. Additionally, one of the greatest methodological problems with any investigation of factors which may confound the cortisol awakening response is one of internal validity. Garde *et al.* (2012) point to the fact that very few studies specifically set out to investigate the association between sleep-related factors and the cortisol awakening response and that is certainly true of the present study.

Contribution of the present results to the thesis.

- High frequency heart rate variability is positively associated with the cortisol awakening response at the within-individual level.
- The cortisol awakening response is associated with nocturnal movement over the latter stages of sleep. Nocturnal activity may provide an indication of stage of sleep prior to awakening which may need to be considered as a covariate.
- There appears to be a lack of evidence to suggest that non-normal cortisol responses are a genuine and meaningful phenomenon.

CHAPTER 9. General discussion

9.1 DISCUSSION OF KEY FINDINGS

This chapter provides a summary of the key findings presented in this thesis and discusses the practical implications of these for the psychophysiological assessment of the interaction between employees and their working environment. Recommendations for future work are also given based upon the present findings. The overall aim of this thesis was to investigate the physiological consequences of work amongst higher education employees, with specific respect to psychosocial hazard and workability. The main findings of the studies reported in this thesis were:

- Chronic exposure to work-related demand, assessed via the Health and Safety Management Standards Indicator Tool, was associated with greater sympathetic dominance of the autonomic nervous system, but not with reactivity of the hypothalamic-pituitary-adrenal axis (Chapter 4).
- Academics reported greater exposure to psychosocial hazard, and poorer workability, than non-academic higher education employees, but no between-group differences were present in either heart rate variability, or the cortisol awakening response (Chapters 4 and 5).
- There was substantial within-individual variation in both the cortisol awakening response and ambulatory heart variability (Chapters 4, 5 and 6).
- The rise in salivary free cortisol over the immediate post awakening period varied according to acute anticipatory demand (Chapter 4).

- Acute work-related demand was associated with ambulatory heart rate variability during work time and evening time at the within-individual level (Chapter 6).
- Acute workload was associated with following day's cortisol awakening response at the within-individual level (Chapter 6).
- The cortisol awakening response was associated with both heart rate variability and nocturnal movement in the latter stage of sleep (Chapter 8).
- Work time activity levels contributed very little to the variation in ambulatory heart rate variability and blood pressure in predominantly sedentary occupations (Chapter 7).
- Salivary free cortisol demonstrated a clear rise on all sampling occasions when compliance was controlled via the use of an accelerometer and a smart electronic pill bottle. (Chapter 8).
- The use of a simple visual analogue scale to obtain a subjective assessment of the acute demands of a working day appears a valid means of assessing an individual's perception of the interaction between the environment and their personal resources (Chapters 4, 5 and 6).

The results of this thesis confirm that the psychosocial work environment is associated with functioning of both the hypothalamic-pituitary-adrenal axis and the autonomic nervous system. Exposure to chronic psychosocial demand, as measured by the Health and Safety Management Standards Indicator Tool, is associated with the sympathovagal balance of the autonomic system during working hours. As no previous attempts have been made to investigate the physiological consequences of work using the Health and Safety Management

Standards Indicator Tool, the finding that the 'demand' standard is associated with heart rate variability during working hours represents an important contribution to the literature.

Perhaps the most significant findings presented in this thesis relate to the presence of intra-individual variation in psychophysiological reactivity to the demands of work. The results presented in chapter 4 suggest that relative acute work-related demand, as assessed by a simple visual analogue scale, is associated with alterations in blood pressure and heart rate variability over the course of the working day. The single-subject case study reported in chapter 6 confirmed there to be substantial day-to-day variation in ambulatory heart rate variability across a greater number of assessment occasions. The results of the case study also expand upon the findings of chapter 4 by revealing acute workload to be associated with ambulatory heart rate variability, both during the working day and in the evening. This appears to be the first time that variation in acute psychosocial demand has been associated with autonomic functioning in higher education employees. Ilies *et al.* (2010) previously reported ambulatory blood pressure to be associated with daily workload amongst higher education employees, whilst Langelotz *et al.* (2008) found heart rate variability to be associated with perceived stress amongst surgeons (Langelotz *et al.*, 2008).

This has significant practical implications for use in the real world. By attending to physiological activation occurring within an individual in response to the acute work environment, it should be possible to determine whether the relationship

between the person and the environment is favourable or not. This could help to identify where some form of intervention is required, which could either involve taking action to alter the environment or to provide the individual with increased resources to cope with the environment. Conversely, on the premise that certain work environments are inherently very high in specific types of demand, and cannot reasonably be altered, it should be possible to identify individuals better equipped to cope with these environments. Numerous occupations include a range of physical and performance assessments as part of their recruitment process. Therefore, assessing heart rate variability during the performance of simulated work tasks could provide valuable information about the potential consequences of the work for a given individual.

Similarly, the results reported in chapter 5 revealed that the cortisol awakening response is also influenced by the relative acute anticipatory demands of the working day. Although previous studies have investigated variation in the cortisol awakening response between workdays and weekend days, this appears to be the first attempt to consider the influence of variation in anticipatory work-related demand upon the response. Therefore, this also represents an important contribution to the literature. The results presented in chapter 5 confirmed there to be substantial intra-individual variation in the cortisol awakening response, although the extent to which variation in anticipatory work-related demand may have influenced this is unclear as no assessment of anticipatory demand was performed. This was a deliberate approach as attending to anticipatory demand may have altered the perception of the day, which may have influenced ambulatory heart rate variability. Nevertheless, the intra-individual variation

shown to occur in the cortisol awakening response is in keeping with the apparent shift in the literature from conceptualising the cortisol awakening response as being highly stable to a position that views it as largely state dependent.

Taken together, the variation in both ambulatory heart rate variability and the cortisol awakening response supports the contention that focusing only on between-individual variation may limit our understanding of the relationship between work and health (Uchino *et al.*, 2012; Ross *et al.* 2014). This has clear implications for research design, with the validity of cross-sectional investigations being threatened unless it can be established how typical an individual's physiological response is at the time of assessment. Even then, given the between-individual variation in the stress response, a longitudinal approach seems more appropriate for investigating the physiological consequences of work. This also has ramifications for the development of valid, reliable and easily applied method of assessing work strain at an early stage based upon physiological assessment. Whilst the information obtained at a single time point may be of limited value, attending to temporal variation may provide a more detailed picture of the extent to which an individual is coping with the demand of work. Therefore, it is important to be able to attend to the acute situation within which any ambulatory assessment is performed.

The results of both the group study and the case study appear to provide support for the validity of using a single item visual analogue scale to obtain a measure of acute work-related demands. This is perhaps an oversimplification, however,

at least in terms of the terminology being used. The question “*how demanding was your day, compared to an average day?*” provides no information as to how demand is being defined, instead relying upon a subjective interpretation of what constitutes a demanding day. Within the stress literature, the concept of work demand is largely understood to be environment and task related, with person-specific factors being separate constructs and it is the interaction between the two that is believed to lead to a stress response. Although the importance of attending to the dynamic of the work environment is increasingly being acknowledged (Ilies et al., 2007; Ilies et al., 2010; Johnston et al., 2013), individuals also demonstrate temporal variability in their psychosocial characteristics, including coping (Carels et al., 2004) and motivation (Totterdell et al., 2006). Therefore, it seems that psychophysiological assessment of work strain should either attend to temporal variation in both work and person-related characteristics, or to the interaction between the two. This raises a methodological consideration regarding the balance between psychometric acceptability and practicality, but single item questionnaires are not without value, especially when combined with multidimensional tools (Bowling, 2005). It is possible that the visual analogue scale represents a more global construct that relates to the interaction between work-related pressure and an individual’s ability to cope with them at a given time. Combining this with multidimensional assessments of chronic psychosocial hazard and health may lead to a greater understanding of the physiological consequences of work strain. However, it is worth noting that causality has not been established, as the assessment of daily demand employed a retrospective approach which involves a process of introspection. It is therefore possible that participants attend to the physiological

sensations of stress when providing a rating of acute demand. Nevertheless, it has previously been argued that introspection provides the most objective measurement of stress (Atz, 2013) and the results presented in this thesis appear to support this.

Assessment of the hypothalamic-pituitary-adrenal axis, via sampling of the cortisol awakening response, and of the autonomic nervous system through ambulatory monitoring of heart rate variability both provide readily assessable indices of disruption to homeostasis. However, the validity of these methods for sampling within a naturalistic environment relies upon the ability to separate the signal from the noise. Compliance with the experimental protocol has previously been identified as representing a potential threat to the validity of the cortisol awakening response (O'Connor *et al.* 2009). The results presented in chapter 5 certainly reinforce this, as 25% of samples were not suitable for inclusion in the final analysis, either due to there being an insufficient volume of saliva provided, or because no increase in cortisol was found over the awakening period. The methodology used for the single-subject case study, presented in chapter 5, confirmed the practical application of controlling for adherence via accelerometry (Kupper *et al.*, 2005) and time stamped electronic smart devices (Kudielka *et al.*, 2003). Furthermore, the results presented in the same chapter suggest that when adherence is adequately controlled for salivary cortisol demonstrates a pronounced increase over the awakening period on all sampling occasions. This supports the earlier findings of both Wilhelm *et al.* (2007) and Stalder *et al.* (2009), which suggests that the findings of previous studies, e.g. Dahlgren *et al.* (2009)

and Eek *et al.* (2006) may have been influenced by the inclusion of negative awakening responses in the data analysis.

Ambulatory monitoring of heart rate variability does not suffer from the same adherence related problems, as there is little responsibility upon the participants and the researcher can easily review the electrocardiogram recording should non-adherence be suspected. Furthermore, the results of chapter 7 also suggest that the level of work-time activity in predominantly sedentary occupations exerts little influence upon measures of spectral parameters of heart rate variability in the low and high frequency ranges. Therefore, in terms of suitability as a practical field-based assessment tool, ambulatory heart rate variability seems preferable to the cortisol awakening response. With technological advances leading to more accessible, minimally invasive micro sensors and smart clothes capable of assessing physiological responses (Dittmar *et al.*, 2004; Lymberis *et al.*, 2004), the possibility of routinely monitoring employees' heart rate variability during work time to obtain an objective measure of the extent to which work represents a potential risk to an individual's health seems a real possibility.

9.2 RECOMMENDATIONS FOR FUTURE WORK

In chapter 4, the finding that heart rate variability only differed significantly from the less to the more demanding day in the academic group, and not the general staff, is worthy of further investigation. Given the differences in reported exposure to chronic psychosocial hazard between the two occupational groups (Kinman and Court, 2010), it may be that the additive effects of chronic and acute stress

account for this finding. Alternatively, it is possible that differences in the type of acute work-related demand may be responsible for this finding. It has certainly been reported that UK university lecturers engage in emotional labour as an everyday part of their working lives (Ogbonna and Harris, 2004) and emotional labour is known to be a considerable source of occupational stress (Mann and Cowburn, 2005).

As the levels of acute demand were relatively low in both studies contained within this thesis, it is recommended that further studies are performed to investigate the physiological responses to higher levels of acute psychosocial work-related demand. Additionally, further investigations should be performed into the validity and reliability of the visual analogue scale used to assess acute demand.

The results of a single-subject case study obviously cannot be extrapolated to a wider population. Therefore, further studies are recommended to investigate whether these results can be replicated. The case study revealed that it is certainly possible to perform a non-invasive repeated assessment of heart rate variability over multiple workdays. Perhaps, therefore, now is the time to move away from the current paradigm which uses physiological markers of the stress response to validate theoretical models and subjective questionnaires at a cross-sectional level, towards a position where an individual's physiological responses to certain organisational and environmental factors is used to identify the determinants of stress activation for that individual.

In chapter 7, consideration was given to the effect that differing epoch length may have upon the relationship between activity and heart rate variability. The data from the case study was investigated using epochs of both 30 minutes and 1 minute. However a similar comparison was not possible for the data obtained in the group study as the software used to analyse the electrocardiogram cannot provide values for heart rate variability over durations as short as a single minute. It would be interesting to confirm the findings relating to the influence of epoch duration within a broader population.

It is also recommended that further investigations are performed to elucidate the involvement of sleep processes in the cortisol awakening response with particular consideration for the effects of nocturnal movement and also stage of sleep immediately prior to awakening. Although the laboratory polysomnogram remains the gold standard for assessment of sleep (Roebuck *et al.*, 2014), the increase in commercially available portable systems capable of monitoring sleep (Kelly *et al.*, 2012) should allow such investigations to be performed whilst retaining the ecological validity afforded by sampling in the naturalistic environment.

9.3 LIMITATIONS

Although the results presented in this thesis support the relationship between psychosocial work-related strain and functioning of the hypothalamic-pituitary-adrenal axis and the autonomic nervous system, it is unclear what the long term health implications of exposure to psychosocial hazard may be. Longitudinal investigations of the relationship between exposure to psychosocial hazard and

negative health outcomes| focusing upon intra-individual variation of physiological functioning| would be valuable.

There are a number of confounding factors which may have influenced the psychophysiological responses observed in the studies reported within this thesis. Personality factors and emotional regulation are known to influence individual responses to stressful stimuli (Saklofske *et al.*, 2012). Certainly, coping strategies are known to mediate the response of the hypothalamic pituitary adrenal axis to stress (Hone *et al.*, 2014). Additionally, although the dynamic nature of the work environment is increasingly being acknowledged it is important that the intra-individuality in factors which may influence an employee's interaction with their environment are not overlooked. Factors such as coping (Carels *et al.*, 2004), emotion, mood and motivation (Totterdell *et al.*, 2006) all demonstrate temporal variability which may also influence the physiological response to acute psychosocial hazard.

References

Aardex (2005) MEMS 6 *Medication Event Monitoring System*. Available from: <https://v2-app.aardexgroup.com/view/Docs/StandardNonIntervention/index.html> [accesses 10th December 2013].

Aboa-Éboulé, C., Brisson, C., Maunsell, E., Mâsse, B., Bourbonnais, R., Vézina, M., Milot, A., Thérout, P. and Dagenais, G. R. (2007) Job strain and risk of acute recurrent coronary heart disease events. *The Journal of the American Medical Association*, **298**(14), 1652-1660.

Acharya, U. R., Joseph, K. P., Kannathal, N., Lim, C. M. and Suri, J. S. (2006) Heart rate variability: a review. *Medical Biological Engineering Computing*, **44**, 1031-1051.

Adam, E. K., Hawkley, L. C., Kudielka, B. M. and Cacioppo, J. T. (2006) Day-to-day dynamics of experience-cortisol associations in a population-based sample of older adults. *Proceedings of the National Academy of Sciences of the United States of America*, **103**(45) 17058-17063.

Ahlstrom, L., Grimby-Ekman, A., Hagberg, M. and Dellve, L. (2010) The work ability index and single-item question: associations with sick leave, symptoms, and health – a prospective study of women on long-term sick leave. *Journal of Work and Environmental Health*, **36**(5), 404-412.

Aittomäki, A., Lahelma, E. and Roos, E. (2003) Work conditions and socioeconomic inequalities in work ability. *Scandinavian Journal of Work and Environmental Health*, **29**(2), 159-165.

Alavinia., S. M., de Boer, A. G. E. M., van Duivenboden, J. C., Frings-Dresen, M. H. W. and Burdorf, A. (2008) Determinants of work ability and its predictive value for disability. *Occupational Medicine*, **59**, 32-37.

Alderling, M., Theorell, T., de la Torre, B. and Lundberg, I. (2006) The demand control model and circadian saliva cortisol variations in a Swedish population based sample (The PART study). *BMC Public Health*, **6**, 288-296.

Almeida, D. M., Piazza, J. R. and Stawski, R. S. (2009) Interindividual variability in the cortisol awakening response: an examination of age and gender. *Psychology and Aging*, **24**(4), 819-827.

Andrea, H., Beurskens, A. J. H. M., Metsemakers, J. F. M., van Amelsvoort, L. G. P. M., van den Brandt, P. A. and van Schayck, C. P. (2003) Health problems and psychosocial work environments as predictors of long term sickness absence in employees who visited the occupational physician and/or general practitioner in relation to work: a prospective study. *Occupational and Environmental Medicine*, **60**, 295-300.

Anosov, O., Patzak, A., Kononovich, Y. And Persson, P. B., (2000) High-frequency oscillations of the heart rate during ramp load reflect the human anaerobic threshold. *European Journal of Applied Physiology*. **83**(4-5), 388-394.

Anshel, M. H. (2000) A conceptual model and implications for coping with stressful events in police work. *Criminal Justice and Behaviour*, **27**, 375-400.

Antelmi, I., De Paula, R. S., Shinzato, A. R., Peres, C. A., Mansur, A. J. and Grupi, C. J. (2004) Influence of age, gender, body mass index, and functional capacity on heart rate variability in a cohort of subjects without heart disease. *The American Journal of Cardiology*, **93**, 381-385.

Aoyagi, N., Ohashi, K. and Yamamoto, Y. (2003) Frequency characteristics of long-term heart rate variability during constant-routine protocol. *American Journal of Physiology Regulatory, Integrative and Comparative Physiology*, **285**(171-176)

Atz, U. (2013) Evaluating experience sampling of stress in a single-subject research design. *Personal and Ubiquitous Computing*, **17**(4), 639-652.

Aubert, A. E., Seps, B. and Beckers, F. (2003) Heart rate variability in athletes. *Sports Medicine*, **33**(12) 889-919.

Backhaus, J., Junghanns, K. and Hohagen, F. (2004) Sleep disturbances are correlated with decreased morning awakening salivary cortisol. *Psychoneuroendocrinology*, **29**(9) 1184-1191.

- Bakker, A. B., Killmer, C. H., Siegrist, J. and Schaufeli, W. B. (2000) Effort-reward imbalance and burnout among nurses. *Journal of Advanced Nursing*, **31**(4), 884-891.
- Bakker, A. B., Demerouti, E. and Schaufeli, W. B. (2003) Dual processes at work in a call centre: An application of the job-demands-resources model. *European Journal of work and Organizational Psychology*, **12**(4), 393-417.
- Bakker, A. B., van Veldhoven, M. and Xanthopoulou, D. (2010) Beyond the demand-control model. Thriving on high job demands and resources. *Journal of Personnel Psychology*, **9**(1), 3-16.
- Balbo M., Leproult, R. and Van Cauter, E. (2010) Impact of sleep and its disturbances on hypothalamo-pituitary-adrenal axis activity. *International Journal of Endocrinology*, **2010**, 1-6.
- Banach, T., Grandys, M., Juszczyk, K., Kolasińska-Kloch, W., Zoladz, Thor, P. J. (2004) Heart rate variability during incremental cycling exercise in healthy untrained young men. *Folia Med Cracov* (abstract only), **45**(1-2), 3-12.
- Barling, J. and Kelloway, E. K. (1996) Job insecurity and health: the moderating role of workplace control. *Stress Medicine*, **12**, 253-259.
- Barrett, L. and Barrett, P. (2007) Current practice in the allocation of academic workloads. *Higher Education Quarterly*, **61**(4), 461-478.
- Bartram, D. J., Yadegarfar, G. and Baldwin, D. S. (2009) Psychosocial working conditions and work-related stressors among UK veterinary surgeons. *Occupational Medicine*, **59**, 334-341.
- Beal, D. J. and Weiss, H. M. (2003) Methods of Ecological Momentary Assessment in Organizational Research. *Organizational Research Methods*, **6**(4), 440-464.
- Beevers, G., Lip, G. Y. H. and O'Brien, E. (2001) ABC of hypertension. Blood pressure measurement. Part I – Sphygmomanometry: factors common to all techniques. *British Medical Journal*, **322**, 981-985.

Bernardi, L., Valle, F., Coco, M., Calciati, A. and Sleight, P. (1996) Physical activity influences heart rate variability and very-low-frequency components in Holter electrocardiograms, *Cardiovascular Research*, **32**, 234-237.

Bethge, M. and Radoschewskim F. M. (2010) Physical and psychosocial work stressors, health-related control beliefs and work ability: cross-sectional findings from the German Sociomedical Panel of Employees. *International Archives of Occupational and Environmental Health*, **83**(3), 241-250.

Bevan, A., Houdmont, J. and Menear, N. (2010) The management standards indicator tool and the estimation of risk. *Occupational Medicine*, **60**, 525-531.

Billman, G. E. (2011) Heart rate variability – a historical perspective. *Frontiers in Physiology*, **2**(86), 1-13.

Bland, J. M. and Altman, D. G. (1995) Calculating correlation coefficients with repeated observations: Part 1 – correlation within subjects. *British Medical Journal*, **310**, 446.

Blascovich, J. and Mendes, W. B. (2000) Challenge and threat appraisals: the role of affective cues. In: Forgas, J. (Ed) *Feeling and Thinking: the role of affect in social cognition* (p59-82) New York: Cambridge University Press.

Blascovich, J., Mendes, W. B., Tomaka, J., Salomon, K. and Seery, M. (2003) The robust nature of the biopsychosocial model challenge and threat: a reply to Wright and Kirby. *Personality and Social Psychology Review*, **7**(3), 234-243.

Bolger, N. and Amarel, D. (2007) Effects of social support visibility on adjustment to stress: experimental evidence. *Journal of Personality and Social Psychology*, **92**(3), 458-475.

Borg V. and Kristensen, T. S. (2000) Social class and self-rated health: can the gradient be explained by differences in life style or work environment. *Social Science and Medicine*, **51**(7), 1019-1030.

Borg, V., Kristensen, T. and Burr, H. (2003) Work Environment and changes in self-rated health: a five-year follow-up study. *Stress Medicine*, **16**, 37-47.

Borsboom, D., Mellenbergh, G. J. Van Heerden. (2003) The theoretical status of latent variables. *Psychological Review*, **110**(2), 203-219.

Bosma, H., Siegrist, J. and Marmot, M. (1998) Two alternative job stress models and the risk of coronary heart disease. *American Journal of Public Health*, **88**(1), 68-74.

Bowling, A. (2005) Just one question: if one question works why ask several? *Journal of Epidemiological Health*, **59**:342-345.

Boyce, W. T., Chesney, M., Alkon, A., Tschann, J. M., Adams, S., Chesterman, B., Cohen, F., Kaiser, P., Folkman, S. and Wara, D. (1995) Psychobiologic reactivity to stress and childhood respiratory illnesses: Results of two prospective studies. *Psychosomatic Medicine*, **57**, 411-422.

Boyce, W. T. and Ellis, B. J. (2005) Biological sensitivity to context: I. An evolutionary-developmental theory of the origins and functions of stress reactivity. *Development and Psychopathology*, **17**, 271-301.

Bradburn, N. M., Rips, L. J. and Shevell, S. K. (1987) Answering autobiographical questions: the impact of memory and inference on surveys. *Science*, **236**, 157-161.

Britton, A., Shipley, M., Malik, M., Hnatkova, K., Hemingway, H. and Marmot, M. (2007) Changes in heart rate and heart rate variability over time in middle-aged men and women in the general population (from the Whitehall II cohort study). *American Journal of Cardiology*, **100**, 524-527.

Britton, A., Singh-Manoux, A., Hnatkova, K., Malik, M., Marmot, M. G. and Shipley, M. (2008) The association between heart rate variability and cognitive impairment in middle-aged men and women. *Neuroepidemiology*, **31**, 115-121.

Brookes, K., Limbert, C., Deacy, C., O'Reilly, A., Scott, S. Thirlaway, K. (2013) Systematic review: work-related stress and the HSE Management Standards. *Occupational Medicine*, **63**(7), 463-472.

Brotman, D. J., Golden, S. H. and Wittstein, I. S. (2007) The cardiovascular toll of stress. *The Lancet*, **370**, 1089-1100.

Brown D. E., James, G. D. and Mills, P. S. (2006) Occupational differences in job strain and physiological stress: Female nurses and school teachers in Hawaii. *Psychosomatic Medicine*, **68**, 524-530.

Cacioppo J. T., Malarkey, W. B., Kiecolt-Glaser, J. K., Uchino, B. N., Sgoutas-Emch, S. A., Sheridan, J. F., Bernston, G. G. and Glaser, R. (1995) Heterogeneity in neuroendocrine and immune responses to brief psychological stressors as a function of autonomic cardiac activation. *Psychosomatic Medicine*, **57**(2), 154-164.

Cacioppo, J. T., Berntson, G. G., Malarkey, W. B., Kiecolt-Glaser, J. K., Sheridan, J. F., Poehlmann, K. M., Bureson, M. H., Ernst, J. M., Hawkley, L. C. and Glaser, R. (1998) Autonomic, neuroendocrine and Immune responses to stress: the reactivity hypothesis. *Annals of the New York Academy of Sciences*, **840**, 664-673.

Calnan, M., Wainwright, D. and Almond, S. (2000) Job strain, effort-reward imbalance and mental distress: a study of occupations in general medical practice. *Work and stress*, **14**(4), 297-311.

Camerino, D., Conway, P. M., Van der Heijden, B. I., Estry-Behar, M., Consonni, D., Gould, D., Hasselhorn, H. M. and The Next Study Group. (2006) Low-perceived work ability, ageing and intention to leave nursing: a comparison among 10 European countries. *Journal of Advanced Nursing*, **56**(5), 542-552.

Capanni, C., Sartori, S., Carpentiero, G. and Costa, G. (2005) Work ability in a cohort of railway construction workers. *International Congress Series*, **1280**, 253-257.

Carels, R. A., Musher-Eizenman, D., Cacciapaglia, H., Perez-Benitez, C. I., Christie, S. and O'Brien, W. (2004) Psychosocial functioning and physical symptoms in heart failure patients: a within-individual approach. *Journal of Psychosomatic Research*, **56**(1), 95-101.

Carney, R. M., Blumenthal, J. A., Stein, P. K., Watkins, L., Catellier, D., Berkman, L. F., Czajkowski, S. M., O'Connor, C., Stone, P. and Freedland, K. E. (2001) Depression, heart rate variability, and acute myocardial infarction. *Circulation*, **104**, 2024-2028.

Carney, R. M., Blumenthal, J. A., Freedland, K. E., Stein, P. K., Howells, W. B., Berkman, L. F., Watkins, L. L., Czajkowski, S. M., Hayano, J., Domitrovich, P. P. and Jaffe, A. S. (2005) Low heart rate variability and the effect of depression on

post-myocardial infarction mortality. *Archives of Internal Medicine*, **165**, 1486-1491.

Carroll, D., Smith, G. D., Shipley, M. J. and Marmot, M. G. (1995) Pressor reactions to psychological stress and prediction of future blood pressure: data from the Whitehall II study. *British Medical Journal*, **310**, 771-775.

Cervone, D. (2005) Personality Architecture: within-person structures and processes. *Annual Review of Psychology*, **56**, 423-452.

Cesana G., Segà, R., Ferrario, M., Chiodini, P., Corrao, G. and Mancia, G. (2003) Job strain and blood pressure in employed men and women: A pooled analysis of four northern Italian population samples. *Psychosomatic Medicine*, **65**, 558-563.

Chandola, T., Britton, A., Brunner, E., Hemingway, H., Malik, M., Kumari, M., Badrick, E., Kivimaki, M. and Marmot, M. (2008) Work stress and coronary heart disease: what are the mechanisms? *European Heart Journal*, **29**, 640-648.

Chapman, L. (2005) Meta-evaluation of worksite health promotion economic return studies. *Art of Health Promotion Newsletter*, **6**(6),

Chida, Y. and Steptoe, A. (2009) Cortisol awakening response and psychosocial factors: a systematic review and meta-analysis. *Biological Psychology*, **80**(3), 265-278.

Chiu, M-C., Wang, M- J. J., Lu, C-W., Pan, S-M., Kumashiro, M. and Ilmarinen, J. (2007) Evaluating work ability and quality of life for clinical nurses in Taiwan. *Nursing Outlook*, **55**, 318-326.

Clow, A., Thorn, L., Evans, P. and Hucklebridge, F. (2004) The awakening cortisol response: Methodological issues and significance. *Stress*, **7**, 29-37.

Clow, A., Edwards, S., Owen, G., Evans, G., Hucklebridge, F. and Casey, A. (2006) Post-awakening cortisol secretion during basic military training. *International Journal of Psychophysiology*, **60**(1), 88-94.

Clow, A., Hucklebridge, F., Stalder, T., Evans, P. and Thorn, L. (2010) The cortisol awakening response: more than a measure of HPA axis function. *Neuroscience and behavioural reviews*, **35**(1), 97-103.

- Cohen, J. (1998) *Statistical power analysis for the behavioural sciences*. Hillsdale, Lawrence Erlbaum Associates.
- Cohen, S., Tyrrell, D. A. J. and Smith, A. P. (1993) Life events, perceived stress, negative affect and susceptibility to the common cold. *Journal of Personality and Social Psychology*, **64**, 131-140.
- Cohen, A. and Golan, R. (1996) Predicting absenteeism and turnover intentions by past absenteeism and work attitude: an empirical examination of female employees in long term nursing care facilities. *Career Development International*, **12**(5), 416-432.
- Cohen, S., Hamrick, N. M. S., Rodriguez, M. S., Feldman, P. J., Rabin, B. S. and Manuck, S. (2000) The stability of and intercorrelations among cardiovascular, immune, endocrine, and psychological reactivity. *Annals of Behavioural Medicine*, **22**(3), 171-179.
- Cohen, S., Hamrick, N., Rodriguez, M. S., Feldman, P. J. Rabin, B. S. and Manuck, S. B. (2002) Reactivity and vulnerability to stress-associated risk for upper respiratory illness. *Psychosomatic Medicine*, **64**, 302-310.
- Cohen, S. and Hamrick, N. (2003) Stable individual differences in physiological response to stressors: implications for stress-elicited changes in immune related health. *Brain, Behaviour, and Immunity*, **17**, 407-414.
- Collins, S. M., Karasek, R. A. and Costas, K. (2005) Job strain and autonomic indices of cardiovascular disease risk. *American Journal of Industrial Medicine*, **42**, 182-193.
- Conner, T., Barrett, L. F. (2012) Trends in ambulatory self-report: The role of momentary experience in psychosomatic medicine. *Psychosomatic Medicine*, **74**(4), 327-337.
- Costa, G., Sartori, S., Bertoldo, B., Olivato, D., Antonacci, G., Ciuffa, V., Mauli, F. (2005) Work ability in health care workers. *International Congress Series*, **1280**, 264-269.
- Cottin, F., Lepretre, P. M., Lopes, P., Papelier, Y., Medigue, C., Billat, V. (2006) Assessment of ventilatory thresholds from heart rate variability in well-trained

subjects during cycling. *International Journal of Sports Medicine*, **27**(12): 959-967.

Cottin, F., Medigue, C., Lopes, P., Lepretre, P. M., Heubert, R., Billat, V. (2006b) Ventilatory thresholds assessment from heart rate variability during an incremental exhaustive running test. *International Journal of Sports Medicine*, **28**(4), 278-294.

Cousins, R., Mackay, C. J., Clarke, S. D., Kelly, C., Kelly, P. J., and McCaig, R. H. (2004) 'Management Standards' and work-related stress in the UK: Practical development. *Work and Stress*, **18**(2), 113-136.

Crawford, J. R. and Henry, J. D. (2010) The positive and negative affect schedule (PANAS): construct validity, measurement properties and normative data in a large non-clinical sample. *British Journal of Clinical Psychology*, **43**(3), 245-265.

Cripps, T. R., Malik, M. and Camm, A. J. (1991) Prognostic value of reduced heart rate variability after myocardial infarction: clinical evaluation of a new analysis method. *British Heart Journal*, **65**, 14-19.

Csikszentmihalyi, M., Larson, R. and Prescott, S. (1977) The ecology of adolescent activity and experience. *Journal of Youth and Adolescence*, **6**(3), 281-294.

Csikszentmihalyi, M. and Larson, R. (1987) Validity and reliability of the experience-sampling method. *Journal of Nervous and Mental Disease*, **175**(9), 526-536.

Curtis, B. M. and O'Keefe, J. H. (2002) Autonomic tone as a cardiovascular risk factor: the dangers of chronic fight or flight. *Mayo Clinic Proceedings*, **77**(1), 45-54.

Dahlgren, A., Kecklund, G., Theorell, T. and Åskerstedt, T. (2009) Day-to-day variation in saliva cortisol – relation with sleep, stress and self-rated health. *Biological Psychology*, **82**, 149-155.

D'Aleo, N., Stebbins, P., Lowe, R., Lees, D. and Ham, D. (2007) Managing workplace stress: psychosocial hazard risk profiles in public and private sector Australia. *The Australian Journal of Rehabilitation Counselling*, **12**, 68-87.

Davig, J. P., Larkin, K. T. and Goodie, J. L. (2000) Does cardiovascular reactivity to stress measured in the laboratory generalize to thesis and dissertation meeting among doctoral students. *International Journal of Behavioural Medicine*, **7**(3), 216-235.

De Bleser, L., De Geest, S., Vanderbroeck, S., Vanhaecke, J. and Dobbels, F. (2010) How Accurate Are Electronic Monitoring Devices? A Laboratory Study Testing Two Devices to Measure Medication Adherence. *Sensors*, **10**, 1652-1660.

De Bruin, G. P. and Taylor, N. (2006) The job demand-control model of job strain across gender. *S A Journal of Industrial Psychology*, **32**(1), 66-73.

De Geus, E. J. C., Kupper, N., Boomsma, D. I. and Snieder, H. (2007) Bivariate genetic modelling of cardiovascular stress reactivity: does stress uncover genetic variance? *Psychosomatic Medicine*, **69**, 356-364.

De Jonge, J. and Kompier, M. A. J. (1997) A critical examination of the demand-control-support model from a work psychological perspective. *International Journal of Stress Management*, **4**(4), 235-258.

De Jonge, J., Mulder, J. G. P. and Nijhuis, F. N. J. (1999) The incorporation of different demand concepts in the job demand-control model: effects of health care professionals. *Social Science and Medicine*, **48**, 1149-1160.

De Jonge, J., Dollard, M. F., Dormann, C., Le Blanc, P. M. and Houtman, I. L. D. (2000) The demand-control model: specific control, and well-defined groups. *International Journal of Stress Management*, **7**(4), 269-287.

De Jonge, J., Bosma, H., Peter, R. and Siegrist, J. (2000a) Job strain, effort-reward imbalance and employee well-being: a large scale cross-sectional study. *Social Science and Medicine*, **50**, 1317-1327.

De Jonge, J., van Veghel, N., Shimazu, A., Schaufeli, W. and Dormann, C. (2010) A longitudinal test of the demand-control model using specific job demands and specific control. *International Journal of Behavioural Medicine*, **17**, 125-133.

Dekker, J. M., Crow, R. S., Folsom, A. R., Hannan, P. J., Liao, D., Swenne, C. A. and Schouten, E. G. (2000) Low heart rate variability in a 2-minute rhythm strip

predicts risk of coronary heart disease and mortality from several causes: The ARIC study. *Circulation*, **102**, 1239-1244.

Demerouti, E., Bakker, A. B., Nachreiner, F. and Schaufeli, W. B. (2001) The job demands-resources model of burnout. *Journal of Applied Psychology*, **86**(3), 499-512.

Dermer, M. L. and Hoch, T. A. (1999) Improving descriptions of single-subject experiments in research texts written for undergraduates. *The Psychological Record*, **49**, 49-66.

Dettenborn, L., Rosenloecher, F. and Kirschbaum, C. (2007) No effects of repeated forced wakings during three consecutive nights on morning cortisol awakening responses (CAR): A preliminary study. *Psychoneuroendocrinology*, **32**(8-10), 915-921.

Devenport, T. J., Biscoombe, K. and Lane, A. M. (2008) Sources of stress and the use of anticipatory, preventative and proactive coping strategies by higher education lecturers. *Journal of Hospitality, Leisure, Sport and Tourism Education*, **7**(1), 70-81.

Dimotakis, N. and Ilies, R. (2012) Experience-sampling and event-sampling research. In: Bakker and Daniels (Eds) *A day in the life of a happy worker*. Hove. Psychology Press.

Dishman, R. K., Nakamura, Y., Garcia, M. E., Thompson, R. W., Dunn, A. L. and Blair, S. N. (2000) Heart rate variability, trait anxiety, and perceived stress among physically fit men and women. *International Journal of Psychophysiology*, **37**, 121-133.

Ditmar, A., Axisa, F., Delhomme C. and Gehin, C. (2004) New concepts and technologies in home care and ambulatory monitoring. *Studies in Health Technology and Informatics*, **108**, 9-35.

Doane, L. D., and Adam, E. K. (2010) Loneliness and cortisol: momentary, day-to-day, and trait associations. *Psychoneuroendocrinology*, **35**(3) 430-441.

Dockray, S. Bhattacharyya, M. R., Molloy, G. J. and Steptoe, A. (2008) The cortisol awakening response in relation to objective and subjective measures of waking in the morning. *Psychoneuroendocrinology*, **33**, 77-82.

Dollard, M. F., Winefield, H. R., Winefield, A. H. and De Jonge, J. (2000) Psychosocial job strain and productivity in human service workers: a test of the demand-control-support model. *Journal of Occupational and Organizational Psychology*, **73**(4), 501-510.

Duijts, S. F. A., Kant, I. Swaen, G. M. H., van den Brandt, P. A. and Zeegers, M. P. A. (2007a) A meta-analysis of observational studies identifies predictors of sickness absence. *Journal of Clinical Epidemiology*, **60**, 1105-1115.

Education Reform Act (1998) London: HMSO

Edwards, J. A., Webster, S., Van Laar, D. and Easton, S. (2008) Psychometric analysis of the UK Health and Safety Executive's Management standards work-related stress indicator tool. *Work and Stress: An International Journal of Work, Health and Organisations*, **22**(2), 96-107.

Edwards, J. A. and Webster, S. (2012) Psychosocial risk assessment: measurement invariance of the UK Health and Safety Executive's Management Standards and work related stress Indicator Tool. *Work and Stress*, **26**, 130-142.

Edwards, S., Evans, P., Hucklebridge, F. and Clow, A. (2001) Association between time of awakening and diurnal cortisol secretory activity. *Psychoneuroendocrinology*, **26**(6), 613-622.

Eek, F. C., Garde, A. H., Hansen, A. M., Persson, R., Orbaek, P. and Karlson, B. (2006) The cortisol awakening response – an exploration of intraindividual stability and negative responses. *Scandinavian Journal of Work and Environmental Health*, **2**, 15–21.

Elder, G. J., Wetherell, M. A., Barclay, N. L. and Ellis, J. G. (2014) The cortisol awakening response – applications and implications for sleep medicine. *Sleep Medicine Reviews*, **18**(3) 215-224.

Eller N. H., Netterstrøm, B. and Hansen, Å, M. (2006) Psychosocial factors at home and at work and levels of salivary cortisol. *Biological Psychology*, **73**, 280-287.

Eller, A. M., Garde, A. H. and Eller, N. H. (2007) Estimation of individual reference intervals in small sample sizes. *International Journal of Hygiene and Environmental Health*, **210**(3-4), 471-478.

Eskelinen, L., Toikkanen, J., Tuomi, K., Mauno, I., Nygard, C. H. and Ilmarinen, J. (1991) Symptoms of mental and physical stress in different categories of municipal work. *Scandinavian Journal of Work and Environmental Health*, **17**, 82-86.

Etzkowitz, H., Webster, A., Gebhardt, C. and Terra, B. R. (2000) The Future of the University and the University of the Future: Evolution of Ivory Tower to 'Entrepreneurial Paradigm'. *Research Policy*, **29**(2), 313-330.

European Commission (2009) *Employment in Europe 2009*. Luxemburg, Directorate-General for Employment, Social Affairs and Equal Opportunities.

Faber, T. S., Staunton, A., Hnatkova, K., Camm, A. J. and Malik, M. (2006) Step wise strategy of using short – and long – term heart rate variability for risk stratification after myocardial infarction. *Pacing and Clinical Electrophysiology*, **19**(1), 1845-1851.

Fahrenberg J. (1996) Ambulatory assessment: issues and perspectives, *In: Fahrenberg and Myrtek, Ambulatory assessment: computer assisted psychological and psychophysiological methods in monitoring and field studies*, Seattle, Hogrefe and Huber, 3-20.

Fauchier, L., Babuty, D., Autret, M. L., Poret, P., Cosnay, P. and Fauchier, J. P. (1998) Influence of duration and hour of recording on spectral measurements of heart rate variability. *Journal of the Autonomic Nervous System*, **73**, 1-6.

Fauvel, J. P., Quelin, P., Ducher, M., Rakotomala, H. and Laville, M. (2001) Perceived job stress but not individual cardiovascular reactivity to stress is related to higher blood pressure at work. *Hypertension*, **38**, 71-75.

Federenko, I. S., Nagamine, M., Hellhammer, D. H., Wadhura, P. D. and Wüst, S. (2004) The heritability of hypothalamus pituitary adrenal responses to psychosocial stress is context dependent. *The Journal of Clinical Endocrinology and Metabolism*, **89**(12), 6244-6250.

Federenko, I., Wüst, S., Hellhammer, D. H., Dechoux, R., Kumsta, R. And Kirschbaum, C. (2004a). Free cortisol awakening responses are influenced by awakening time. *Psychoneuroendocrinology*, **29**, 174-184.

Ferrie, J., Shipley, M., Stansfield, S. and Marmot, M. (2002) Effects of chronic job insecurity and change in job security on self reported health, minor psychiatric morbidity, physiological measures, and health related behaviours in British civil servants: The Whitehall II study. *Journal of Epidemiology and Community Health*, **56**, 450-454.

Filaire, E., Portier, H., Massart, A., Ramat, L. and Teixeira, A. (2010) Effect of lecturing to 200 students on heart rate variability and alpha-amylase activity. *European Journal of Applied Physiology*, **108**, 1035-1043.

Fishel, S. R., Muth, E. R. and Hoover, A. W. (2007) Establishing appropriate physiological baseline procedures for real-time physiological measurement. *Journal of Cognitive Engineering and Decision Making*, **1**(3), 286-308.

Flaa, A., Eide, I. K., Kjeldsen, S. E. and Rostrup, M. (2008) Sympathoadrenal stress reactivity is a predictor of future blood pressure: An 18-year follow up study. *Hypertension*, **53**, 336-341.

Frankenhaeuser M. (1991). The psychophysiology of workload, stress, and health: comparison between the sexes. *Annals of Behavioural Medicine* **13**,197–204.

Fredrickson, B. L. and Kahneman, D. (1993) Duration neglect in retrospective evaluations of affective episodes. *Journal of Personality and Social Psychology*, **65**(1), 45-55.

Friedman, B. H. (2003) Idiodynamics vis-à-vis psychophysiology: An idiodynamic Portrayal of Cardiovascular Reactivity. *Journal of Applied Psychoanalytical Studies*, **5**(4), 425-441.

- Fries, E., Dettenborn, L. and Kirschbaum, C. (2009) The cortisol awakening response (CAR): facts and future directions. *International Journal of Psychophysiology*, **72**(1), 67-73.
- Fullager, C. J. and Kelloway, E. K. (2009) 'Flow at work: an experience sampling approach. *Journal of Occupational and Organizational Psychology*, **82**, 595-615.
- Gaab, J., Rohleder, N., Nater, U. M., Ehlert, U. (2005) Psychosocial determinants of the cortisol stress response: the role of anticipatory cognitive appraisal. *Psychoneuroendocrinology*, **30**, 599 – 610.
- Galinier, M., Pathak, A., Fourcade, J., Androdias, J., Curnier, D., Varnous, S., Boveda, S., Massabuau, P., Fauvel, M., Senard, J. M. and Bounhourne, J. P. (2000) Depressed low frequency power of heart rate variability as an independent predictor of sudden death in chronic heart failure. *European Heart Journal*, **21**, 475-482.
- Gamperiene, M., Nygård, J. F., Sandanger, I., Lau, B. and Bruusgaard, D. (2008) Self-reported work ability of Norwegian women in relation to physical and mental health, and to the work environment. *Journal of Occupational Medicine and Toxicology*, **3**(1), 8- 16.
- Garcia-Tabar, I., Sanchez-Medina, L., Aramendi, J. F., Ruesta, M., Ibanez, J. and Gorostiaga, E. M. (2013) Heart rate variability thresholds predict lactate thresholds in professional world-class road cyclists. *Journal of Exercise Physiology*, **16**(5), 38- 50.
- Garde, A. H., Albertson, K., Persson, R., Hansen, A. M. and Regulies, R. (2012) Bi-directional associations between psychological arousal, cortisol, and sleep. *Behavioural Sleep Medicine*, **10**(1), 28-40.
- Geissler, H., Tempel, J. and Geissler-Gruber, B. (2005) Can the work ability index also be used by non-medical professionals? A comparative study. *International Congress Series*, **1280**, 281-285.
- Gianaros, P. J., May, J. C., Siegle, G. J. and Jennings, J. R. (2005) Is there a functional neural correlate of individual differences in cardiovascular reactivity? *Psychosomatic Medicine*, **67**, 31-39.

Gianaros, P. J., Jennings, J. R., Sheu, L. K., Derbyshire, S. W. G. And Matthews, K. A. (2007) Heightened functional neural activation to psychological stress covaries with exaggerated blood pressure reactivity. *Hypertension*, **49**, 134-140.

Gibb, J., Cameron, I. M., Hamilton, R., Murphy, E. and Naji, S. (2010) Mental health nurses' and allied health professionals' perceptions of the role of the Occupational Health Service in the management of work-related stress: how do they self-care? *Journal of Psychiatric Mental Health Nursing*, **17**, 838-845.

Gillespie, N. A., Walsh, M., Winefield, A. H., Dua, J. and Stough, C. (2001) Occupational stress in universities: Staff perceptions of the causes, consequences and moderators of stress. *Work & Stress: An International Journal of Work, Health & Organisations*, **15**(1), 53-72.

Goedhard, R. G. and Goedhard, W. J. A. (2005) Work ability and perceived work stress. *International Congress Series*, **1280**, 79-83.

Goldberger, J. J. (1999) Sympathovagal balance: how should we measure it? *American Journal of Physiology – Heart and Circulatory Physiology*, **276**, 1273-1280.

Goldstein, I. B., Shapiro, D., Chicz-DeMet, A. and Guthrie, D. (1999) Ambulatory blood pressure, heart rate, and neuroendocrine responses in women nurse during work and off work days. *Psychosomatic Medicine*, **61**, 387-396.

Gori, S., Ficca, G., Giganti., Di Nasso, I., Murri, L. and Salzarulo, P (2004) Body movements during night sleep in healthy elderly subjects and their relationships with sleep stages. *Brain Research Bulletin*, **63**, 393-397.

Grasso, R., Schena, F., Gulli, G. and Cevesse, A. (1997) Does low-frequency variability of heart period reflect a specific parasympathetic mechanism? *Journal of the Autonomic Nervous System*, **63**, 30-38.

Gröschl, M. (2008) Current status of salivary hormone analysis. *Clinical Chemistry*, **54**(11) 1759-1769.

Grossman, P., Wilhelm, F. H. and Spoerle, M. (2004) Respiratory sinus arrhythmia, cardiac vagal control, and daily activity. *American Journal of Physiology, Heart and circulatory physiology*, **278**, 728-734.

Geurts, S. A. E., Kompier, M. A. J., Roxburgh, S. and Houtman, I. L. D. (2003) Does work-home interference mediate the relationship between workload and wellbeing? *Journal of Vocational Behaviour*, **63**(3), 532-559.

Guest, D (2004) Flexible employment contracts, the psychological contract and employee outcomes: an analysis and review of the evidence. *International Journal of Management Reviews*, **5-6**(1), 1-19.

Guidi, S., Bagnara, S. and Fichera, G. P. (2012) The HSE indicator tool, psychosocial distress and workability. *Occupational Medicine*, **62**, 203-209.

Guimont, C., Brisson, C, Dagenais, G. R., Milot, A., Vézina, M., Mâsse, B., Moisan, J., Laflamme, N. and Blanchette, C. (2006) Effects of job strain on blood pressure: A prospective study of male and female white collar-workers. *American Journal of Public Health*, **96**(8), 1436-1443.

Gyllensten, K. and Palmer, S. (2005) The relationship between coaching and workplace stress: A correlational study. *International Journal of Health Promotion and Education*, **43**(3), 97-103.

Haberkorn, J., Burbaum, C., Fritzsche, K., Geser, W., Fuchs, D., Ocaña-Peinado, F. M. and Schubert, C. (2013) Day-to-day cause–effect relations between cellular immune activity, fatigue and mood in a patient with prior breast cancer and current cancer-related fatigue and depression, *Psychoneuroendocrinology*, **38**(10), 2366–2372.

Hackett, A., Palmer, S. and Farrants, J. (2009) Phase 1 of an investigation into levels of stress in United Kingdom hospice services. *International Journal of Palliative Nursing*, **15**, 66-72.

Hamaker, E. L. and Dolan, C. V. (2005) Statistical modelling of the individual: rationale and application of multivariate stationary time series analysis. *Multivariate Behavioural Research*, **40**(2), 207-233.

Hautala, A. J., Karjalainen, J., Kiviniemi, A. M. Kinnunen, H., Makikallio, H., Huikuri, H. V. and Tulppo, M. P. (2010) Physical activity and heart rate variability measured simultaneously during waking hours. *American Journal of Physiology: Heart and Circulatory Physiology*, **298**, 874-880.

Hall, M., Vasko, R., Buysse, D., Ombao, H., Chen, Q., Cashmere, J. D., Kupfer, D. and Thayer, J. F. (2004) Acute stress affects heart rate variability during sleep. *Psychosomatic Medicine*, **66**(1), 56-62.

Hansen A. M., Garde, A. H. Eller, n. H. (2007) Estimation of individual reference intervals in small sample sizes. *International Journal of Hygiene and Environmental Health*, **210**(3-4) 471-478.

Hansen, A. M., Blangsted, A. K., Hansen, E. A., Sogaard, K. and Sjogaard, G. (2010) Physical activity, job demand-control, perceived stress-energy, and salivary cortisol in white collar workers. *International Archives of Occupational and Environmental Health*, **83**, 143-153.

Hansen, A. M., Thomsen, J. F., Kaergaard, A., Kolstad, H. A. Kaerlev, L and Mors, O. (2012) Salivary cortisol and sleep problems among civil servants. *Psychoneuroendocrinology*, **37**, 1086–1095.

Hanson, E. K. S., Godaert, G. L. R., Maas, C. J. M. and Meijman, T. F. (2001) Vagal cardiac control throughout the day: the relative importance of effort-reward imbalance and within-day measurements of mood, demand and satisfaction. *Biological Psychology*, **56**, 23-44.

Hassellund, S. S., Flaa, A., Sandvik, L., Kjeldson, S. E. and Rostrip, M. (2010) Long-term stability of cardiovascular and catecholamine responses to stress tests: An 18-year follow up study. *Hypertension*, **55**, 131-136.

Health and Safety Executive (2001) *A critical review of psychosocial hazard measures*. London, HSE.

Health and Safety Executive (2005). *HSE Management Standards Indicator Tool*. Available at:<http://www.hse.gov.uk/stress/standards/pdfs/indicatortool.pdf>. [accessed 10th January 2013].

Health and Safety Executive (2007) *HSE Management Standards Analysis Tool*. Available at: <http://www.hse.gov.uk/stress/standards/downloads.html> [accessed 10th January 2013].

Health and Safety Executive (2009) *How to tackle work-related stress*. London, HSE.

- Hellhammer, D. H., Wüst, S. and Kudielka, B. M. (2009). Salivary cortisol as a biomarker in stress research. *Psychoneuroendocrinology*, **34**, 163-171.
- Herbert, T. B., Cohens, S., Marsland, A. L., Bachen, E. A., Rubin, N., Muldoon, M. F. and Manuck, S. B. (1994) Cardiovascular reactivity and the course of immune response to an acute psychological stressor. *Psychosomatic Medicine*, **56**, 337-344.
- Hinkle, L. E., and Wolff, H. G. (1958) Ecologic investigations of the relationship between illness, life experiences and the social environment. *Annals of International Medicine*, **49**, 1373-1388
- Hjortskov, N., Rissén, D., Blangsted, A. K., Fallentin, N., Lundberg, U. and Søgaard, K. (2004) The effect of mental stress on heart rate variability and blood pressure during computer work. *European Journal of Applied Physiology*, **92**, 84-89.
- Ho, M., Peterson, P. N. and Masoudi, F. A. (2008) Key issues in outcomes research. *Circulation*, **118**, 1675-1684.
- Ho, R. C. M., Neo, L. F., Chua, A. N. C., Cheak, A. A. A. and Mak, A. (2010) Research on psychoneuroimmunology: does stress influence immunity and cause coronary artery disease? *Annals Academy of Medicine Singapore*, **39**, 191-196.
- Höhne, N., Poidinger, M., Merz, F., Pfister, H., Brückl, T., Zimmermann, P., Uhr, M., Holsboer, F. and Ising, M. (2014) Increased HPA axis response to psychosocial stress in remitted depression: the influence of coping style. *Biological Psychology*, **103**, 267-275.
- Hohnloser, S., Klingenhoben, T., Zabel, M. and Li, Y. G. (1997) Heart rate variability used as an arrhythmia risk stratifier after myocardial infarction. *Pacing and Clinical Electrophysiology*, **20**(10), 2594-2601.
- Hopf, H. B., Skyschally, A., Heusch, G. and Peters, J. (1995) Low-frequency spectral power of heart rate variability is not a specific marker of cardiac sympathetic modulation. *Anesthesiology*, **82**, 609-619.

Houdmont, J., Kerr, R. and Randall, R. (2012) Organisational psychosocial hazard exposures in UK policing: management standards indicator tool reference values. *Policing: An international Journal of Police Strategies and Management*, **35**(1), 182-197.

Houle, M. S. and Billman, G. E. (1999) Low-frequency component of the heart rate variability spectrum: a poor marker of sympathetic activity. *American Journal of Physiology – Heart and Circulatory Physiology*, **276**, 215-223.

Houston, D., Meyer, L. H. and Paewai, S. (2006) Academic staff workloads and job satisfaction: expectations and values in academe. *Journal of Higher Education Policy and Management*, **28**(1), 17-30.

Hruschka, D. J., Kohrt, B. A. and Worthman, C. M. (2005) Estimating between – and within-individual variation in cortisol levels using multilevel models. *Psychoneuroendocrinology*, **30**, 698-714.

Hucklebridge, F., Clow, A., Rahman, H. and Evans, P (2000) The cortisol response to normal and nocturnal awakening. *Journal of Psychophysiology*, **14**(1) 24-28.

Hucklebridge, F., Mellins, J., Evans, P. and Clow, A. (2002) The awakening response: No evidence for an influence of body posture. *Life sciences*, **71**, 639-646.

Hucklebridge, F., Hussain, T., Evans, P. and Clow, A. (2005). The diurnal patterns of the adrenal steroids cortisol and dehydroepiandrosterone (DHEA) in relation to awakening, *Psychoneuroendocrinology*, **30**(1), 51-57.

Huikuri, H. V., niemela, M. J., Ojala, S., Rantala, A., Ikaheimo, M. J. and Airaksinen, K. E. (1994) Circadian rhythms of frequency domain measures of heart rate variability in healthy subjects and patients with coronary artery disease. Effects of arousal and upright posture. *Circulation*, **90**, 121-126.

Huikuri, H. V. and Stein, P. K. (2012) Clinical application of heart rate variability after acute myocardial infarction. *Frontiers in Physiology*, **3**(41), 1-5.

Hurlburt R. T. and Knapp, T. J. (2006) Munsterberg in 1989, not Allport in 1937, introduced the terms 'idiographic' and 'nomothetic' to American psychology. *Theory and Psychology*, **16**(2), 287-293.

Ilies, R. and Judge, T. A. (2002) Understanding the dynamic relationships among personality, mood, and job satisfaction: a field experience sampling study. *Organizational Behaviour and Human Decision Processes*, **89**, 1119-1139.

Ilies, R. and Judge, T. A. (2004) An experience-sampling measure of job satisfaction and its relationships with affectivity, mood at work, job beliefs, and general job satisfaction. *European Journal of Work and Organizational Psychology*, **13**(3), 367-389.

Ilies, R., Schwind, K. M., Wagner, D. T., Johnson, M. D., DeRue, D. S. and Ilgen, D. R. (2007) When can employees have a family life? The effects of daily workload and affect on work-family conflict and social behaviours at home. *Journal of Applied Psychology*, **92**(5), 1368-1379.

Ilies, R., Dimotakis, N. and De Pater, I. E. (2010) Psychological and Physiological reactions to high workloads: implications for well-being. *Personnel Psychology*, **63**, 407-436.

Ilmarinen, J., Tuomi, K. and Klockars, M. (1997) Changes in the work ability of active employees over an 11-year period. *Scandinavian Journal of Work and Environmental Health*, **23**(supp 1), 49-57.

Ilmarinen, J. (2007) The Work Ability Index (WAI). *Occupational Medicine*, **57**, 160.

Izawa, S., Sugaya, N., Yamamoto, R., Ogawa, N. and Nomura, S. (2010) The Cortisol Awakening Response and Autonomic Nervous System Activity During Nocturnal and Early Morning Periods. *Neuro Endocrinology Letters*, **31**(5), 685-689.

Jansen, B. H., Shankar, K. (1993) Sleep staging with movement-related signals. *International Journal of Bio-Medical Computing*, **32**(3-4), 289-297.

Jennings, J. R., Kamarck, T., Stewart, C., Eddy, M. Johnson, P. (1992) Alternate cardiovascular baseline assessment techniques: vanilla or resting baseline. *Psychophysiology*, **29**(6), 42-50.

Johnson, J. V. and Hall, E. M. (1988) Job strain, work place social support, and cardiovascular disease: A cross-sectional study of a random sample of the Swedish working population. *American Journal of Public Health*, **78**(10), 1336-1342.

Johnson, J. V., Stewart, W., Hall, E. M., Fredlund, P. and Theorell, T. (1996) Long-term psychosocial work environment and cardiovascular mortality among Swedish men. *American Journal of Public Health*, **86**(3), 324-331.

Johnson, S., Cooper, C., Cartwright, S., Donald, I., Taylor, P. and Millet, C. (2005) The experience of work-related stress across occupations. *Journal of Managerial Psychology*, **20**(2), 178-187.

Johnston, D. W., Jones, M. C., Charles, K., McCann, S. K. and McKee, L. (2013) Stress in nurses: stress related affect and its determinants examined over the nursing day. *Annals of Behavioural Medicine*, **45**(3), 348-356.

Jones, M.V., Meijen, C., McCarthy, P.J., & Sheffield, D. (2009). A theory of challenge and threat states in athletes. *International Review of Sport and Exercise Psychology*, **2**(2), 161–180.

Jourdain, G. and Chênevert, D. (2010) Job-demands-resources, burnout and intention to leave the nursing profession: A questionnaire survey. *International Journal of Nursing*, **47**(6), 709-722.

Kahn, M., Sheppes, G. and Sadeh, A. (2013) Sleep and emotions: bidirectional links and underlying mechanisms, *International Journal of Psychophysiology*, **89**(2), 218-228.

Kaletka, D., Makowiec-Babrowska, T. and Jeiger, A. (2006) Lifestyle index and work ability. *International Journal of Occupational Medicine and Environmental Health*, **19**(3), 170-177.

Kamarck, T. W., Manuck, S. B. and Jennings, J. R. (1990) Social support reduces cardiovascular reactivity to psychological challenge: a laboratory model. *Psychosomatic Medicine*, **52**(1), 42-58.

Kamarck, T. and Lovallo, W. (2003) Cardiovascular reactivity to psychological challenge: conceptual considerations. *Psychosomatic Medicine*, **F**(1), 9-21.

Kamarck, T. W., Schwartz, J. E., Shiffman, S., Muldoon, M. F., Sutton-Tyrell, K. and Janicki, D. L. (2005) Psychosocial stress and cardiovascular risk: what is the role of daily experience? *Journal of Personality*, **73**(6), 1749-1774.

Kamarck, T. W., Muldoon, M. F., Shiffman, S. S., Sutton-Tyrell, K. (2007) Experiences of demand and control during daily life are predictors of carotid atherosclerotic progression among healthy men. *Health Psychology*, **26**(3), 324-332.

Karapetian, G. K., Engels, H. J., Gretebeck, R. J. (2008) Use of heart rate variability to estimate LT and VT. *International Journal of Sports Medicine*, **29**, 652-657.

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

Karasek, R., Baker, D., Marxer, F., Ahlbom, A. and Theorell, T. (1981) Job decision latitude, job demands and cardiovascular disease: A prospective study of Swedish men. *American Journal of Public Health*, 1981, **16**, 463-467.

Karasek, R. (2008) Low social control and logical deregulation – the stress-disequilibrium theory, towards a new demand-control model. *Scandinavian Journal of Work, Environment and Health*, **6**, 117-135.

Karemaker, J. M. (2001) The riddles of heart rate variability. *Clinical Autonomic Research*, **11**, 65-66.

Kearney, P. M., Whelton, M., Reynolds, K., Muntner, P., Whelton, P. K. and He, J. (2005) Global burden of hypertension: analysis of worldwide data. *The Lancet*, **365**(9455), 217-223.

Kelly, J. M., Strecker, R. E., Bianchi, M. T. (2012) Recent developments in home sleep-monitoring devices. *International Scholarly Research Notices*, 768794, 1-10.

Kelsey, R. M., Ornduff, S. R. and Alpert, B. S. (2007) Reliability of cardiovascular reactivity to stress: internal consistency. *Psychophysiology*, **44**, 216-225.

Kerr, R., McHugh, M. and McCrory, M. (2009) HSE management standards and stress-related work outcomes. *Occupational Medicine*, **29**, 574-579.

Khan, M., Sheppes, G. and Sadeh, A. (2013) Sleep and emotions: Bidirectional links and underlying mechanisms. *International Journal of Psychophysiology*, **89**, 218-228.

Kim, D. H., Lipsitz, L. A., Ferrucci, L., Varadhan, R., Guralnik, T. M., Carlson, M. C., Fleisher, L. A., Fried, L. P. and Chaves, P. H. M. (2006) Association between reduced heart rate variability and cognitive impairment in older disabled women in the community: women's health and aging study I. *Journal of the American Geriatrics Society*, **54**(11), 1751-1757.

Kinman, G. and Jones, F. (2003) 'Running up the down escalator': stressors and strains in UK academics. *Quality in Higher Education*, **9**(1), 21-38.

Kinman, G. and Court, S. (2010) Psychosocial hazards in UK universities: adopting a risk assessment approach. *Higher Education Quarterly*, **64**(4), 413-428.

Kirschbaum, C., Wust, S., Faig, H. G. and Hellhammer, D. H. (1992) Heritability of cortisol responses to human corticotrophin-releasing hormone, ergometry and psychological stress in humans. *Journal of Clinical Endocrinology and Metabolism*, **75**, 1526-1530.

Kirschbaum, C. and Hellhammer, D. (1994) Salivary cortisol in psychoneuroendocrine research: recent developments and applications. *Psychoneuroendocrinology*, **19**(4) 313-333.

Kirschbaum, C. and Hellhammer D. H. (1999) Noise and stress – salivary cortisol as a non-invasive measure of allostatic load. *Noise and Health*, **1**(4), 57-65.

Kirschbaum, C. (2010.) *Salivary cortisol technical Issues*. Research: Allosattic Load Notebook, MacArthur,

Kiss, P., Walgrave, M. and Vanhoorne, M. (2002) Assessment of work ability in aging fire fighters by means of the work ability index preliminary results. *Archives of Public Health*, **60**, 233-243.

Kikuya, M., Hozawa, A., Ohokubo, T., Ichiro, T., Michimata, M., Matsubara, M., Ota, M., Nagai, K., Araki, T., Satoh, H., Ito, S., Hisamichi, S. and Imai, Y. (2000) Prognostic significance of blood pressure and heart rate variabilities: The Ohasama study, *Hypertension*, **36**, 901-906.

Kizildere S, Glück T, Zietz B, and Schölmerich J, Straub RH.(2003) During a corticotropin-releasing hormone test in healthy subjects, administration of a beta-adrenergic antagonist induced secretion of cortisol and dehydroepiandrosterone sulfate and inhibited secretion of ACTH. *European Journal of Endocrinology*, **148**(1), 45-53.

Kloimüller. I., Karazman, R., Geissler, H., Karazman-Morawetz, I. and Haupt, H. (2000) The relation of age, work ability index and stress-inducing factors among bus drivers. *International Journal of Industrial Ergonomics*, **25**, 497-502.

Knezevic, B., Milosevic, M., Golibic, R., Belosevic, L., Russo, A. and Mustajbegovic, J. (2009) Work-related stress and work ability among Croatian university hospital midwives. *Midwifery*, **2**, 146-153.

Kop, W. J., Verdino, R. J., Gottdiener, J. S., Herz, C. N. B. and Krantz, D. S. (2001) Changes in heart rate and heart rate variability before ambulatory ischemic events. *Journal of the American College of Cardiology*, **38**, 742-749.

Kožená, L., Frantík, E. and Horváth, M. (1998) Cardiovascular reaction to job stress in middle-aged train drivers. *International Journal of Behavioural Medicine*, **5**(4), 281-294.

Krantz, G. and Ostengren, P. O. (2002) Do common symptoms in women predict long spells of sickness absence? A prospective community-based study on Swedish women 40 to 50 years of age. *Scandinavian Journal of Public Health*, **30**(3), 176-183.

Kristiansen, J., Korshøj, Skotte, J. H., Jepsen, T., Sogaard, K., Mortensen, O. S. and Holterman, A. (2011) Comparison of two systems for long-term heart rate variability monitoring in free-living conditions – a pilot study. *Biomedical Engineering Online*, **10**(27), 10-27.

Kristjansson, S. D., Kircher, J. C. and Webb, A. K. (2007) Multilevel models for repeated measures designs in psychophysiology: An introduction to growth curve modelling, *Psychophysiology*, **44**, 728-736.

Kubiak, T. and Stone, A. A. (2012) Ambulatory monitoring of biobehavioral processes in health and disease. *Psychosomatic Medicine*, **74**, 325 -326.

Kudielka, B. M., Broderick, J. E. and Kirschbaum, C. (2003) Compliance with saliva sampling protocols: electronic monitoring reveals invalid cortisol daytime profiles in noncompliant subjects. *Psychosomatic Medicine*, **65**, 313-319.

Kudielka, B. M. And Kirschbaum, C. (2003) Awakening cortisol responses are influenced by health status and awakening time but not by menstrual cycle phase. *Psychoneuroendocrinology*, **28**, 35-47.

Kudielka, B. M. and Kirschbaum, C. (2005) Sex differences in HPA axis response to stress: a review. *Biological Psychology*, **69**, 113-132.

Kudielka, B. M., Hawkey, L. C., Adam, E. K. and Cacioppo, J. T. (2007) Compliance with ambulatory saliva sampling in the Chicago health, aging, and social relations study and associations with social support. *Annals of Behavioural Medicine*, **34**(2), 209-216.

Kujala, V., Remes, J., Ek, E., Tammelin, T. and Laitinen, J. (2005) Classification of work ability index among young employees. *Occupational Medicine*, **55**, 399-401.

Kujala, V., Tammelin, T., Remes, J., Vammavaara, E., Ellen, E. K. and Laitinen, J. (2006) Work ability of young employees and their sickness absence during the following year. *Scandinavian Journal of Work and Environmental Health*, **32**(1), 75-84.

Kumari, M., Badrick, E., Ferrie, J., Perski, A., Marmot, M. and Chandola, T. (2009) Self-reported sleep duration and sleep disturbances are independently

associated with cortisol secretion in the Whitehall II study. *Journal of Clinical Endocrinology and Metabolism*, **94**(12), 4801-4809.

Kunz-Ebrecht, S. R., Kirschbaum, C. and Steptoe, A. (2004a). Work stress, socioeconomic status and neuroendocrine activation over the working day. *Social Science and Medicine*, **58**, 1523-1530.

Kunz-Ebrecht, S. R., Kirschbaum, C., Marmot, M. and Steptoe, A. (2004b) Differences in cortisol awakening response on work days and weekends in women and men from the Whitehall II cohort. *Psychoneuroendocrinology*, **29**, 516-528.

Kuo, T. B. J., Lin, T., Yang, C. C. H., Li, C. H., Chen, C. F. and Chou, P. (1999) Effect of aging on gender differences in neural control of heart rate. *American Journal of Physiology – Heart and Circulatory Physiology*, **46**, 2233-2239.

Kuper, H., Singh-Manoux, A., Siegrist, J. and Marmot, M. (2002) When reciprocity fails: effort-reward imbalance in relation to coronary heart disease and health functioning within Whitehall II study. *Occupational Environmental Medicine*, **59**(11), 777-784.

Kupper, N., de Geus, E. J. C., van den Berg, M., Kirschbaum, C., Boomsma, D. I. and Willemsen, G. (2005) Familial influences on basal salivary cortisol in an adult population. *Psychoneuroendocrinology*, **30**(9), 857-868.

Kuss, O., Schumann, B., Kluttig, A., Greiser, M. H. and Haerting, J. (2008) Time domain parameters can be estimated with less statistical error than frequency domain parameters in the analysis of heart rate variability. *Journal of Electrocardiology*, **41**, 287-291.

Lai, J. C. L., Evans, P., Ng, S. H., Chong, A. M. L., Siu, O. T., Chan, C. L. W., Ho, S. M. Y., Ho, R. T. H., Plato, C. and Chan, C. C. (2005) Optimism, positive affectivity, and salivary cortisol. *British Journal of Health Psychology*, **10**, 467-484.

Lai, J. C. L., Chong, A. M. L., Siu, O. T., Evans, P., Chan, C. C. and Ho, R. T. H. (2010) Humour attenuates the cortisol awakening response in older men. *Biological Psychology*, **84**(2), 375-380.

Lam, A. (2010) From 'Ivory Tower Traditionalists' to entrepreneurial Scientists. Academic scientists in fuzzy university boundaries. *Social Studies of Science*, **40**(2), 307-340.

Landsbergis, P. A., Schnall, P. L., Pickering, T. G., Warren, K. and Schwartz, J. E. (2003) Lower socioeconomic status among men in relation to the association between job strain and blood pressure. *Scandinavian Journal of Work and Environmental Health*, **29**(3), 206-215.

Landsbergis, P. A., Schnall, P. L., Pickering, T. G., Warren, K. and Schwartz, J. E. (2003a) Life-course exposure to job strain and ambulatory blood pressure in men. *American Journal of Epidemiology*, **157**, 998-1006.

Landsbergis, P. A., Schnall, P. L., Belkić, K. L., Schwartz, J. E., Baker, D. and Pickering, T. G. (2008) Work conditions and masked (hidden) hypertension – insights into the global epidemic of hypertension. *Scandinavian Journal of Work and Environmental Health Supplements*, **6**, 41-51.

Langelotz, C., Scharfenberg, M., Haase, O. and Schwenk, W. (2008) Stress and heart rate variability in surgeons during a 24-hour shift, *Archives of Surgery*, **143**(8), 751-755.

Lara-Carasco, J., Nielsen, T. A., Solomonova, E., Levrier, E., Popova, A. (2009) Overnight emotional adaptation to negative stimuli is altered by REM sleep deprivation and is correlated with intervening dream emotions. *Journal of Sleep Research*, **18**, 178-187.

La Rovere, M. T., Pinna, G. D., Maestri, R., Mortara, A., Capomolla, S., Febo, O., Ferrari, R., Franchini, M., Gnemmi, M., Opasich, C., Riccardi, P. G., Traversi, E. and Cobelli, F. (2003) Short-term heart rate variability strongly predicts sudden cardiac death in chronic heart failure patients. *Circulation*, **107**, 565-570.

Larson, M. R., Ader, R. and Moynihan, J. A. (2001) Heart rate, neuroendocrine, and immunological reactivity to an acute laboratory stressor. *Psychosomatic Medicine*, **63**, 493-501.

Lasikiewicz, N., Hendriks, H., Talbot, D. and Dye, L. (2008) Exploration of basal diurnal salivary cortisol profiles in middle-aged adults: associations with sleep quality and metabolic parameters. *Psychoneuroendocrinology*, **33**, 143-151.

László, K. D., Pikhart, H., Kopp, M. S., Bobak, M., Pajak, A., Malyutina, S., Salavec, G. and Marmot, M. (2010) Job insecurity and health: a study of 16 European countries. *Social Science and Medicine*, **70**, 867-874.

Lenth, R. V. (2001) Some practical guidelines for effective sample size determination. *The American Statistician*, **55**(3), 187-193.

Lesage, F. X. and Berjot, S. (2011) Validity of occupational stress assessment using a visual analogue scale. *Occupational Medicine*, **61**(6), 434-436.

Levine, L. J. and Safer, M. A. (2002) Sources of bias in memory for emotions. *Current directions in psychological science*, **11**, 169-173.

Levine, A., Zagoory-Sharon, O., Feldman, R., Lewis, J. G. Weller, A. (2007) Measuring cortisol in human psychobiological studies. *Physiology and Behaviour*, **90**(1), 43-53.

Levy, W. C., Cerqueira, M. D., Harp, G. D., Johannessen, K. A., Abrass, I. B., Schwartz, R. S. and Stratton, J. R. (1998) Effect of endurance exercise training on heart rate variability at rest in healthy young and older men. *American Journal of Cardiology*, **82**, 1236-1241.

Liao, D., Cai, J., Barnes, R. W., Tyroler, H. A., Rautaharju, P., Holme, I., Heiss, G. (1996) Association of cardiac autonomic function and the development of hypertension: the ARIC study. *American Journal of Hypertension*, **9**, 1147-1156.

Liao, D., Cai, J., Rosamond, W. D., Barnes, R. W., Hutchinson, R. G., Whitsel, E. A., Rautaharju, P. and Heiss, G. (1997) Cardiac Autonomic Function and Incident Coronary Heart Disease: A Population-based Case-Cohort Study: The ARIC Study. *American Journal of Epidemiology*, **145**(8), 696-706.

Liberzon, J., Abelson, J. L., King, A., Liberzon, I. (2008) Naturalistic stress and cortisol response to awakening: adaptation to seafaring. *Psychoneuroendocrinology*, **33**, 1023-1026.

Licht, C. M. M., Vreeburg, S. A., Van Reedt Dortland, A. K. B., Giltay, E. J., Hoogendijk, W. J. G., DeRijik, R. H., Vogelzangs, N., Zitman, F. G., De Geus, E. J. C. and Pennix, W. J. H. (2009) Increased sympathetic and decreased parasympathetic activity rather than changes in hypothalamic-pituitary-adrenal

axis activity is associated with metabolic abnormalities. *The Journal of Clinical Endocrinology and Metabolism*, **95**(5), 2458-2466.

Light, K. C., Turner, J. and Hinderliter, A. L. (1992) Job strain and ambulatory work blood pressure in healthy young men and women. *Hypertension*, **20**, 214-218.

Lindberg, P., Vingård, E., Josephson, M. and Alfredsson, L. (2005) Retaining the ability to work – associated factors at work. *European Journal of Public Health*, **16**(5), 470-475.

Lindberg, P., Josephson, M., Alfredsson, L. and Vingård, E. (2006) Promoting excellent work ability and preventing poor work ability: the same determinants? Results from the Swedish HAKuL study. *Occupational and environmental Medicine*, **63**, 113-120.

Loerbroks, A., Schilling, O., Haxsen, V., Jarczok, M. N., Thayer, J. F. and Fischer, J. E. (2010) The fruits of ones labour: Effort-reward imbalance but not job strain is related to heart rate variability across the day in 35-44 year old workers. *Journal of Psychosomatic Research*, **69**(2), 151-159.

Looser, R. R., Mentzenthin, P., Helfricht, S., Kudielka, B. M., Loerbroks, A., Thayer, J. F. and Fischer, J. E. (2010) Cortisol is significantly correlated with cardiovascular responses during high levels of stress in critical care personnel. *Psychosomatic Medicine*, **72**, 281-289.

Lovallo, W. R. (2010) Do low levels of stress reactivity signal poor states of health? *Biological Psychology*, **86**(2), 121-128.

Lucini, D., Mela, G. S., Malliani, A. and Pagani, M. (2002a) Impairment in cardiac autonomic regulation preceding arterial hypertension in humans. Insights from spectral analysis of beat-by-beat cardiovascular variability. *Circulation*, **106**, 2673-2679.

Lucini, D., Norbiato, G., Clerici, M. and Pagani, M. (2002b) Hemodynamic and autonomic adjustments to real life stress conditions in humans. *Hypertension*, **39**, 184-188.

Lucini, D., Di Fede, G., Parati, G. and Pagani, M. (2005) Impact of chronic psychosocial stress on autonomic cardiovascular regulation in otherwise healthy subjects. *Hypertension*, **46**, 1201-1206.

Lucini, D., Riva, S., Pizzinelli, P. and Pagani, M. (2007) Stress management at the worksite. Reversal of symptoms profile and cardiovascular dysregulation. *Stress and Hypertension*, **49**, 291-297.

Lundberg, U. and Frankenhaeuser, M. (1980) Pituitary-adrenal and sympathetic-adrenal correlates of distress and effort. *Journal of Psychosomatic Research*, **24**(3-4), 125-130.

Lymberis, A. (2004) Research and development of smart wearable health applications: the challenge ahead. *Studies in health technology and informatics*. **108**, 155-161.

McKay, C. J., Cousind, R. and Kelly, P. J. (2004) 'Management Standards' and work-related stress in the UK: policy background and science. *Work and Stress: An International Journal of Work, Health and Organisations*, **18**(2), 91-112.

McNamara, P., Auerbach, S., Johnson, P., Harris, E. and Doros, G. (2010) Impact of Rem sleep on distortions of self-concept, mood and memory in depressed/anxious participants. *Journal of Affective Disorders*, **122**, 198-207.

Magnavita, N. (2012) Validation of the Italian version of the HSE Indicator Tool. *Occupational Medicine*, **62**, 288-294.

Maimy, V. I. (2006) Spectral analysis and interpretation of spectral components of heart rate variability. *Human Physiology*, **32**(2), 169-176.

Maina, G., Palmas, A., Bovenzi, M. and Filon, F. L. (2009a). Salivary cortisol and psychosocial hazards at work. *American Journal of Industrial Medicine*, **52**, 251-260.

Maina, G., Bovenzi, M., Palmas, A. and Fillon, F. L. (2009b). Associations between two job stress models and measures of salivary control. *International Archives of Occupational and Environmental Health*, **82**, 1141-1150.

Malliani A., Lombardi, F. and Pagani, M. (1994) Power spectrum analysis of heart rate variability: a tool to explore neural regulatory mechanisms. *British Heart Journal*, **71**(1), 1-2.

Malliani, A. (2005) Heart rate variability: from bench to bedside. *European Journal of Internal Medicine*, **16**, 12-20.

Mancia, G., Sega, R., Bravi, C., DeVito, G., Valagussa F., Cesana, G., and Zanchetti, A. (1995) Ambulatory blood pressure normality: results from the PAMELA study. *Journal of Hypertension*, **13**(12), 1377-1390.

Mann, S. and Cowburn, J. (2005) Emotional labour and stress within mental health nursing. *Journal of Psychiatric and Mental Health Nursing*, **12**(2), 154-162.

Marsland, A. L. Bachen, E. A., Cohen, S., Rabin, B., and Manuck, S. B. (2002) Stress, immune reactivity and susceptibility to infectious disease. *Physiology and Behavior*, **77**, 711-716.

Matsuda, S., Yamaguchi, T., Okada, K., Gotouda, A. and Mikami, S. (2012) Day-to-day variations in salivary cortisol measurements. *Journal of prosthodontic research*, **56**(1), 37-41.

Matthews, K. A., Woodall, K. L. and Allen, M, T. (1993) Cardiovascular reactivity to stress predicts future blood pressure status. *Hypertension*, **22**, 479-485.

Meersman, R. E. D. (1993) Heart rate variability and aerobic fitness. *American Heart Journal*, **125**(3) 726-731.

Meier, L. L., Gross, S., Spector, P.E. and Norbet, K. (2013) Relationship and task conflict at work: interactive short-term effects on angry mood and somatic complaints. *Journal of Occupational Health Psychology*, **81**(2), 144-156.

Mendel, C. M. (1989) The free hormone hypothesis: a physiologically based mathematical model. *Endocrine Reviews*, **10** (3), 232- 274.

Mendonca, G. V., Fernhall, B., Heffernan, K. S. and Pereira, F. D. (2009) Spectral methods of heart rate variability analysis during dynamic exercise. *Clinical Autonomic Research*, **19**(4), 237-245.

Menkes, M. S., Matthews, K. A., Krantz, D. S., Lundberg, V., Mead, L. A., Quaqish, B., Liang, K. Y., Thomas, C. B. and Pearson, T. A. (1989) Cardiovascular reactivity to the cold pressor test as a predictor of hypertension. *Hypertension*, **14**, 524-530.

Melin, B., and Lundberg, U. (1997). A biopsychosocial approach to work-stress and musculoskeletal disorder. *Journal of Psychophysiology*, **11**, 238-247

Mikolajczak, M., Quoidbach, J., Vanootighem, V., Lambert, F., Lahaye, M., Fillée, C. and de Timary, P. (2009) Cortisol awakening response (CAR)'s flexibility leads to larger and more consistent associations with psychological factors than CAR magnitude. *Psychoneuroendocrinology*, **35**(5), 752-757.

Miller, D. B. and O'Callaghan, J. P. (2002) Neuroendocrine aspects of the response to stress. *Metabolism*, **51**(6), 5-10.

Miller, R., Plessow, F., Kirschbaum, C. and Stalder, T. (2013) Classification criteria for distinguishing cortisol responders from nonresponders to psychosocial stress: evaluation of salivary cortisol pulse detection in panel designs. *Psychosomatic Medicine*, **75**(9), 832-840.

Miner, A. G., Glomb, T. M and Hulin, C. (2005) Experience sampling mood and its correlates at work. *Organisational Psychology*, **78**(2), 171-193.

Moak, J. P., Goldstein, D. S., Eldadah, B. A., Saleem, A., Holmes, C., Pechnik, S. and Sharabi, Y. (2009) Supine low-frequency power of heart rate variability reflects baroreflex function, not cardiac sympathetic innervation. *Cleveland Clinical Journal of Medicine*, **76**(2), S51-S59.

Molenaar, P. C. M. (2004) A manifesto on psychology as idiographic science: bringing the person back into scientific psychology, this time forever, *Measurement: Interdisciplinary Research and Perspective*, **2**(4), 201-218.

Molenaar, P. C. M. (2007) Psychological methodology will change profoundly due to the necessity to focus on intra-individual variation. *Integrated Psychological and Behavioural Science*, **41**, 35-40.

Molenaar, P. C. M. and Campbell, C. G. (2009) The new person-specific paradigm in psychology. *Current Directions in Psychological Science*, **18**(2), 112-117.

Montano, N., Ruscone, T. G., Pata, A., Lombardi, F., Pagani, M. and Malliani, A. (1994) Power spectrum analysis of heart rate variability to assess the changes in sympathovagal balance during graded orthostatic tilt. *Circulation*, **90**, 1826-1831.

Montano, N., Porta, a., Cogliati, C., Costantino, G., Tobaldini, E., Casali, K. R. and Iellamo, F. (2009) Heart rate variability explored in the frequency domain: a tool to investigate the link between heart and behaviour. *Neuroscience and Behavioural Reviews*, **33**(2), 71-80.

Monteiro, M. S., Ilmarinen, J. And Corraa Filho, H. R. (2006) Work ability of workers in different age groups in a public health institution in Brazil. *International Journal of Safety and Ergonomics*, **12**(4), 417-427.

Moreau, M., Valente, F., Mak, R., Pelfrene, E., de Smet, P., De Backer, G. and Kornitzer, M. (2004) Occupational stress and incidence of sick leave in the Belgian workforce: the Belstress study. *Journal of Epidemiological Community Health*, **58**, 507-516.

Mourad, A., Carney, S., Gillies, A., Jones, B., Nanra, R. and Trevillian, P. Arm position and blood pressure: a risk factor for hypertension? *Journal of Human Hypertension*, **17**, 389-395.

Muller, K. E. and Benignus, V. A. (1992) Increasing scientific power with statistical power. *Neurotoxicology and Teratology*, **14**(3), 211-219.

Muzet, A., Naitoh, P., Townsend, R. E. and Johnson, L. C. (1972) Body movements during sleep as a predictor of stage change, *Psychonomic Science*, **29**(1), 7-10.

Nagrão, A. B., Deuster, P. A., Gold, P. W., Singh, A. and Chrousos, G. P. (2000) Individual reactivity and physiology of the stress response. *Biomedicine and Pharmacotherapy*, **54**(3), 122-128.

Nicolson, N. A. and Van Diest, R. (2000) Salivary cortisol patterns in vital exhaustion. *Journal of Psychosomatic Research*, **49**(5), 335-342.

Nicolson, N. A. (2008) Measurement of Cortisol. In: Luecken, L.J. and Gallo, L. C. Handbook of Physiological Research Methods in Health Psychology. London, Sage.

Niedhammer, I, Bugel, I., Goldberg, M., Leclerc, A. and Geugen, A. (1998) Psychosocial factors at work and sickness absence in the Gazel cohort: A prospective study. *Occupational and Environmental Medicine*, **55**, 735-741.

Nübling, M., Stöbel, U., Hasselhorn, H-M., Michaelis, M. and Hofmann, F. (2006) Measuring psychological stress at work: Evaluation of the COPSOQ questionnaire in Germany. *Psychosocial Medicine*, **3**, 1-14.

O'Brien, E., Asmar, R., Beilin, L., Imai, Y., Mallion, J. M., Mancia, G., Mengden, T., Myers, M., Padfield, P., Palatini, P., Parati, G., Pickering, T., Redon, Staessen, J. M., Stergiou, G. and Verdecchia, P, on behalf of the European Society of Hypertension Working Group on Blood Pressure Monitoring. (2003) *Journal of Hypertension*, **21**, 821-848.

O'Connor, D. B., O'Connor, R. C., White, B. L. and Bundred, P. E. (2000). Job strain and ambulatory blood pressure in British general practitioners: a preliminary study. *Psychology, health and medicine*, **5**(3), 241-249.

O'Connor, D. B., Hendrickx, H., Dadd, T., Elliman, T. D., Willis, T. A., Talbot, D., Mayes, A. E., Thethi, K., Powell, J. and Dye, L. (2009) Cortisol awakening rise in middle-aged women in relation to psychological stress. *Psychoneuroendocrinology*, **34**, 1486-1494.

Ogbonna, E. Harris, L. C. (2004) Work intensification and emotional labour among UK university lecturers: an exploratory study. *Organization Studies*, **25**, 1185-1203.

Ohkubo, T., Kikuya, M., Metoki, H., Asayama, K., Obara, T., Hashimoto, J., Totsune, K., Hoshi, H., Satoh, H., Imai, Y. (2005) Prognosis of "masked" hypertension and "white-coat" hypertension detected by 24-h ambulatory blood pressure monitoring: 10-year follow-up from the Ohasama study. *Journal of the American college of cardiology*, **46**(3), 508-515.

Okun, M. L., Krafty, R. T., Buysse, D. J., Monk, T. H., Reynolds III, C. F., Begley, A. and Hall, M. (2009). What constitutes too long of a delay? Determining the

cortisol awakening response (CAR) using self-report and PSG-assessed wake time. *Psychoneuroendocrinology*, **35**(3), 460-468.

Orizio, C., Perini, R., Comandè, A., Castellano, M., Beschi, M. and Veicsteinas, A. (1988) Plasma catecholamines and heart rate at the beginning of muscular exercise in man. *European Journal of Applied Physiology and Occupational Physiology*, **57**(5), 644-651.

Osterheus, H. H., Hanzel, S. R., Kochs, M. and Hombach, V. (1997) Influence of physical activity on 24-hour measurements of heart rate variability in patients with coronary artery disease. *American Journal of Cardiology*, **80**(11), 1434-1437.

Ostry, A. S., Kelly, S., Demes, P. A., Mustard, C. and Hertzman, C. (2003) A comparison between the effort-reward imbalance and demand control models. *BMC Public Health*, **3**(10), 1-9.

Padgerr, D. A. and Glaser, R (2003) How stress influences the immune response. *Trends in Immunology*, **24**(6), 444-448.

Pal, G. K., Pal, P., Nanda, N., Amudharaj, D., Karthik, S. (2009) Spectral analysis of heart rate variability (HRV) may predict the future development of essential hypertension. *Medical Hypotheses*, **72**, 183-185.

Park, S. W., Brenneman, M. T., Cooke, W. H., Cordova, A. Fogt, D. L. (2014) Determination of anaerobic threshold by heart rate or heart rate variability using discontinuous cycle ergometry. *International Journal of Exercise Science*, **7**(1), 45-53.

Pattyn, N., Migeotte, P. F., Neyt, X., den Nest, A. and Cluydts, R. (2010) Comparing real-life and laboratory-induced stress reactivity on cardio-respiratory parameters: differentiation of a tonic and a phasic component. *Physiology and Behaviour*, **101**(2), 218-223.

Pelfrene, E., Vlerick, P., Kittel, F., Mak, R. P., Kornitzer, M. and De Backer, G. (2002) Psychological work environment and psychological well-being: assessment of the buffering effects in the job-demand-control-(support) model in Belstress. *Stress and Health*, **18**, 43-56.

Perini, R. and Veicsteinas, A. (2003) Heart rate variability and autonomic activity at rest and during exercise in various physiological conditions. *European Journal of Applied Physiology*, **90**, 317-325.

Peter, R., Alfredsson, L., Hammar, N., Siegrist, J., Theorell, T. and Westerholm, P. (1998) High effort, low reward, and cardiovascular risk factors in employed Swedish men and women: baseline results from the WOLF study. *Journal of Epidemiology and Community Health*, **52**, 540-547.

Phillips, A. C. (2010) Blunted cardiovascular reactivity relates to depression, obesity, and self-reported health. *Biological Psychology*, **86**(2), 106-113.

Pickering, T. G., Hall, J. E., Appel, L. J., Falkner, B. E., Graves, J., Hill, M. N., Jones, D. W., Kurtz, T., Sheps, S. G. and Roccella, E. J. (2005) Recommendations for blood pressure measurement in humans and experimental animals: Part 1: Blood pressure measurement in humans: A statement for professionals from the subcommittee of professional and public education of the American Heart Association Council on high blood pressure research. *Circulation*, **111**, 697-716.

Pohjonen, T. (2001) Perceived work ability of home care workers in relation to individual and work-related factors in different age groups. *Occupational Medicine*, **51**, 209-217.

Pollard, T. M., Ungpakorn, G., Harrison, G. A. and Parkes, K. R. (1996) Epinephrine and cortisol responses to work: A test of the models of Frankenhaeuser and Karasek. *Annals of Behavioural Medicine*, **18**, 229-237.

Ponikowski, P., Anker, S. D., Chua, T. P., Szelemej, R., Piepoli, M., Adamopoulos, S., Webb-Peploe, K., Harrington, D., Banasiak, W., Wrabec, K. and Coats, A. J. S. (1997) Depressed heart rate variability as an independent predictor of death in chronic congestive heart failure secondary to ischemic or idiopathic dilated cardiomyopathy. *American Journal of Cardiology*, **79**, 1645-1650.

Potter, P. T., Smith, B. W., Strobel, K. R. and Zautra, A. J. (2002) Interpersonal workplace stressors and well-being: a multi-wave study of employees with and without arthritis. *Journal of Applied Psychology*, **87**(4), 789-796.

Powell, D. J. and Schlotz, W. (2012) Daily life stress and the cortisol awakening response: testing the anticipation hypothesis. *PlosOne*, **7**(12), 1-10.

Preussner, J. C., Wolf, O. T., Hellhammer, D. H., Buske-Kirschbaum, A., von Auer, K., Jobst, S., Kaspers, F. and Kirschbaum, C. (1997). Free cortisol levels after awakening: A reliable biological marker for the assessment of adrenocortical activity. *Life sciences*, **61**(26), 2539-2549.

Preussner, J. C., Kirschbaum, C., Meinlschmid, G. and Hellhammer, D. H. (2003). Two formulas for computation of the area under the curve represent measures of total hormone concentration versus time-dependent change. *Psychoneuroendocrinology*, **28**, 916-931.

Preussner, M., Hellhammer, D. H., Preussner, J. C. and Lupien, S. J. (2003b). Self-reported depressive symptoms and stress levels in healthy young men: Associations with the cortisol response to awakening. *Psychosomatic Medicine*, **65**, 92-99.

Proost, K., De Witte, K., Evers, G. (2004) Burnout among nurses: extending the job demand-control-support model with work-home interface. *Psychologica Belgica*, **44**(4), 269-290.

Pumprla, J., Howorka, K., Groves, D., Chester, M. and Nolan, J. (2002) Functional assessment of heart rate variability: physiological basis and practical applications. *International Journal of Cardiology*, **84**(1), 1-14.

Riese, H., Van Doornen, L. J. P., Houtman, I. L. D. and De Geus, E. J. C. (2004) Job strain in relation to ambulatory blood pressure, heart rate, and heart rate variability among female nurses. *Scandinavian Journal of Work and Environmental Health*, **30**(6), 477-485.

Rimmele, U., Zellweger, B. C., Marti, B., Seiler, R., Mohiyeddini, C., Ehlert, U. and Heinrichs, M. (2007) Trained men show lower cortisol, heart rate and psychological responses to psychosocial stress compared with untrained men. *Psychoneuroendocrinology*, **32**(6), 627-635.

Rimmele, U., Seiler, R., Marti, B., Wirtz, P. M., Ehlert, U. and Heinrichs, M. (2009) The level of physical activity affects adrenal and cardiovascular reactivity to psychosocial stress. *Psychoneuroendocrinology*, **34**(2), 190-198.

Robinson, O. C. (2011) The idiographic / nomothetic dichotomy: Tracing historical origins of contemporary confusions. *History and Philosophy of Psychology*, **13**(2), 32-29.

Robinson, B. F., Epstein, S.E., Beiser, G. D. and Braunwald, E. (1996) Control of heart rate by the autonomic nervous system: studies in man on the interrelation between baroreceptor mechanisms and exercise. *Circulation Research*, **19**, 400-411.

Roebuck, A., Monasterio, V., Gederi, E., Osipov, M., Behar, J., Malhotra, T. And Clifford, G. D. (2014) A review of signals used in sleep analysis. *Institute of Physics and Engineering in Medicine*, **35**, 1-57.

Rosengren, A., Hawken, S., Ôunpuu, S., sliwa, K., Zubaid, M., Almahmeed, W. A., Blackett, K. N., sitthi-amorn, C., Sato, H. and Yusuf, S. (2004) Association of psychosocial risk factors with risk of acute myocardial infarction in 11 119 cases and 13 648 controls from 52 countries (the INTERHEART study): case-control study. *Lancet*, **364**, 953-962.

Ross, K. M., Murphy, M. L. M., Adam, E. K., Chen, E. and Miller, G. E. (2014) How stable are diurnal cortisol activity indices in healthy individuals? Evidence from three multi-wave studies. *Psychoneuroendocrinology*, **39**, 184-193.

Rotenberg, S. and McGrath, J. J. (2014) Sampling compliance upon awakening in children and adolescents. *Psychoneuroendocrinology*, **40**, 69-75.

Rozin, P. (2009) What kind of empirical research should we publish, fund, and reward? A different perspective. *Perspectives on Psychological Science*, **4**(4), 435-439.

Ryan, J. F., Healy, R. and Sullivan, J. (2012) Oh, won't you stay? Predictors of faculty intent to leave a public research university. *Higher Education*, **63**(4), 421-437.

Rydstedt, L. W., Devereux, J. and Sverke, M. (2007) Comparing and combining the demand-control-support model and the effort reward imbalance model to predict long-term mental stress. *European Journal of Work and Organizational Psychology*, **16**(3), 261-278.

Saklofske, D. H., Austin, E. J., Mastoras, S. M., Beaton, L. and Osborne, S. E. (2012) Relationships of personality, affect, emotional intelligence and coping with student stress and academic success: Different patterns of association for stress and success. *Learning and Individual Differences*, **22**(2), 251-257.

Salvador, A. Suay, F., González-Bono, E. and Serrano, M. A. (2003) Anticipatory cortisol, testosterone and psychological responses to judo competition in young men. *Psychoneuroendocrinology*, **28**, 346-375.

Salvatore, S. and Valsiner, J. (2010) Between the general and the unique: Overcoming the nomothetic versus idiographic opposition. *Theory and Psychology*, **20**(6), 817-833.

Sandercock, G. (2007) Normative values, reliability and sample size estimates in heart rate variability. *Clinical Science*, **113**, 129-130.

Santavirta, N., Kovero, C. and Solovieva, S. (2005) Psychosocial work environment, well-being and emotional exhaustion. A study comparing five age groups of female workers within the human sector. *International Congress Series*, **1280**, 130-135.

Sarstedt (2010) Salivette: Hygienic saliva collection for diagnostics and monitoring. Available at: <http://www.sarstedt.com/pdf/prospekte/en/156.pdf> (accessed 13/4/2014).

Schaufeli, W. B., Bakker, A. B. and Van Rhenen, W. (2009) How changes in job demands and resources predict burnout, work engagement, and sickness absenteeism. *Journal of Organizational Behaviour*, **30**(7), 893-917.

Schlotz, W., Hellhammer, J., Schultz, P. and Stone, A. A. (2004). Perceived work overload and chronic worrying predict weekend – weekday differences in the cortisol awakening response. *Psychosomatic Medicine*, **66**, 207-214.

Schnall, P. L., Schwartz, J. E., Landsbergis, K. W. and Pickering, T. G. (1992) Relation between job strain, alcohol, and ambulatory blood pressure. *Hypertension*, **19**, 488-494.

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

Schnell, I., Potchter, O., Epstein, Y., Yaakov, Y., Hermesh, H., Brenner, S. and Tirosh, E. (2013) The effects of exposure to environmental factors on Heart Rate Variability: An ecological perspective, *Environmental Pollution*, **183**, 7-13.

Schrijvers, C., van de Mheen, D., Stronks, K. and Mackenbach, L. (1998) Socioeconomic inequalities in health and in the working population: the contribution of working conditions. *International Journal of Epidemiology*, **27**, 1011-1018.

Schroeder, E. B., Liao, D., Chambless, L. E., Prineas, R. J., Evans, G. W. and Heiss, G. (2003) Hypertension, blood pressure, and heart rate variability: The atherosclerosis risk in communities (ARIC) study. *Hypertension*, **42**, 1106-1111.

Schultz, P., Schlotz, W. and Becker, P. (2004) Trier inventory for chronic stress (TICS). Gottingen, Germany.

Schwartz, A. R., Gerin, W., Davidson, K. W., Pickering, T., Brosschot, J. F., Thayer, J. F., Christenfeld, N. and Linden, W. (2003) Toward a causal model of cardiovascular responses to stress and the development of cardiovascular disease. *Psychosomatic Medicine*, **65**, 22-35.

Scollon, C. N., Kim-Prieto, C. and Diener, E. (2003) Experience sampling: promises and pitfalls, strengths and weaknesses. *Journal of Happiness Studies*, **4**, 5-34.

Seltman, H. (2013) Within-subjects designs. In: Seltman, H. *Experimental Design and Analysis*, Pittsburgh, Carnegie Mellon University.

Serrador, J. M., Finlayson, H. C. and Hughson, R. L. (1999) Physical activity is a major contributor to the ultra-low frequency components of heart rate variability. *Heart*, **82**, 1-6.

Sgoutas-Emch, S. A., Cacioppo, J. T., Uchino, B. N., Malarkey, W., Pearl, D., Kiecolt-Glaser, J. K. and Glaser, R. (1994) The effects of an acute physiological stressor on cardiovascular, endocrine, and cellular immune response: a

prospective study of individuals high and low in heart rate reactivity. *Psychophysiology*, **31**, 264-271.

Shiffman, S., and Stone, A. A. (1998) Introduction to the special section: ecological momentary assessment in health psychology. *Health Psychology*, **17**(1), 3-5.

Shiffman, S., Stone, A. A. and Hufford, M. R. (2008) Ecological momentary assessment. *Annual Review of Clinical Psychology*, **4**, 1-32.

Shimohira, M., Shiiki, T., Sugimoto, J., Ohsawa, Y., Fukumizu, M., Hasegawa, T., Iwakawa, Y., Nomura, Y. and Segawa, M. (2008). Video analysis of gross body movements during sleep. *Psychiatry and Clinical Neurosciences*, **52**, 176-177.

Shultz, K. S., Wang, M., Crimmins, E. M. and Fisher, G. G. (2010) Age differences in the demand-control model of work stress. An examination of data from 15 European countries, *Journal of Applied Gerontology*, **29**(1), 21-47.

Siegrist, J., Siegrist, K. and Weber, I. (1986) Sociological concepts in the etiology of chronic disease: the case of ischemic heart disease. *Social Science and Medicine*, **22**(2), 247-253.

Siegrist, J., Starke, D., Chandola, T., Godin, I., Marmot, M., Niedhammer, I. and Peter, R. (2004) The measurement of effort-reward imbalance at work: European comparisons. *Social Science and Medicine*, **58**, 1483-1499.

Siegrist, J. (2008) Effort–reward imbalance and health in a globalized economy. *Scandinavian Journal of Work and Environmental Health*, **6**, 163–168.

Singh, J. P., Larson, M. G., Tsuji, H., Evans, J. C., O'Donnell, C. J. and Levy, D. (1998) Reduced heart rate variability and new-onset hypertension. Insights into pathogenesis of hypertension: The Framingham heart study, *Hypertension*, **32**, 293-297.

Singh, A., Petrides, J. S., Gold, P. W., Chrousos, G. P. and Deuster, P.A. (1999) Differential hypothalamic-pituitary-adrenal axis reactivity to psychosocial and

physical stress. *The Journal of Clinical Endocrinology and Metabolism*, **84**, 1944-1948.

Sjögren-Rönjka, T., Ojanen, M. T., Leskinen, E. K., Mustalampi, S. T. and Mälikä, E. A. (2002) Physical and psychosocial prerequisites of functioning in relation to work ability and general subjective well-being among office workers. *Scandinavian Journal of Work and Environmental Health*, **28**(3), 184-190.

Skinner, B.F. (1953). *Science and human behaviour*. New York: MacMillan.

Sloan, R. P., Shapiro, P. A., Bagiella, E., Boni, S. M., Paik, M., Bigger, J. T., Steinman, R. C. and Gorman, J. M. (1994) Effect of mental stress throughout the day on cardiac autonomic control. *Biological Psychology*, **37**, 89-99.

Smyth, J. M. and Stone, A. A. (2003) Ecological momentary assessment research in behavioural medicine. *Journal of Happiness Studies*, **4**, 35-52.

Smyth, N., Clow, A., Thorn, L., Hucklebridge, F. and Evans, P. (2013) Delays of 5-15 min between awakening and the start of saliva sampling matter in assessment of the cortisol awakening response. *Psychoneuroendocrinology*, **38**(9), 1476-1483.

Sonnentag, S. and Bayer, U-V (2005) Switching off mentally: predictors and consequences of psychological detachment from work during off-job time. *Journal of Occupational Health Psychology*, **10**(4), 393-414.

Soo-Quee Koh, D. and Choon-Huat Kot, G. (2007) The use of salivary biomarkers in occupational and environmental medicine. *Occupational and Environmental Medicine*, **64**, 202-210.

Spalding, T. W., Lyon, L. A., Steel, D. H. and Hatfield, B. D. (2004) Aerobic exercise training and cardiovascular reactivity to psychological stress in young normotensive men and women. *Psychophysiology*, **41**(4), 552-562.

Sparks, K. and Cooper, C. L. (1999) Occupational differences in the work-strain relationship: Towards the use of situation-specific models. *Journal of Occupational and Organizational Psychology*, **72**, 219-229.

Spieler, D. K., Hagins, M., Rundle, A. and Pappas, E. A comparison of energy expenditure estimates from the Actiheart and Actical physical activity monitors

during low intensity activities, walking, and jogging. *European Journal of Physiology*, **111**, 659-667.

Stalder, T., Hucklebridge, F., Evans, P. and Clow, A. (2009). Use of a single case study design to examine the state variation in the cortisol awakening response: Relationship with time of awakening. *Psychoneuroendocrinology*, **34**, 607-614.

Stalder, T., evans, P., Hucklebridge, F. and Clow, A. (2010) State associations with the cortisol awakening response. *Psychoneuroendocrinology*, **35**, 1245-1252.

Stalder, T., Evans, P., Hucklebridge, F. and Clow, A. (2011) Associations between the cortisol awakening response and heart rate variability. *Psychoneuroendocrinology*, **36**(4), 454-462.

Stein, P. K., Domitrovich, P. P., Huikuri, H. V. and Kleiger, R. E. (2005) Traditional and nonlinear heart rate variability are independently associated with mortality after myocardial infarction. *Journal of Cardiovascular Electrophysiology*, **16**(1), 13-20.

Steptoe, A., Cropley, M., Griffith, J. and Kirschbaum, C. (2000) Job strain and anger expression predict early morning elevations in salivary cortisol. *Psychosomatic Medicine*, **62**, 286-292.

Steptoe, A., Siegrist, J., Kirschbaum, C. and Marmot, M. (2004) Effort-reward imbalance, overcommitment, and measures of cortisol and blood pressure over the working day. *Psychosomatic Medicine*, **66**(3), 323-329.

Steptoe, A., Hamer, M. and Chida, Y. (2007) The effects of acute psychological stress on circulating inflammatory factors in humans: a review and meta-analysis. *Brain Behaviour and Immunity*, **21**(7), 901-912.

Stern, R. M., Ray, W. J. and Quigley, K. S. (2001) *Psychophysiological recording*. New York, Oxford University Press.

Stone, A. A. and Shiffman, S. (1994) Ecological momentary assessment (EMA) in behavioural medicine. *Annals of Behavioural Medicine*, **16**(3), 199-202.

Stone, A. A., Schwartz, J. E., Smyth, J., Kirschbaum, C., Cohen, S., Hellhammer, D. and Grossman, S. (2001). Individual differences in the diurnal cycle of salivary

free cortisol: a replication of flattened cycles for some individuals. *Psychoneuroendocrinology*, **26**, 295-306.

Stone, A. A., Schwartz, J. E., Broderick, J. E. and Shiffman, S. S. (2005) Variability of momentary pain: a consequence of the peak (or salience) memory heuristic. *Personality and Social Psychology Bulletin*, **31**(10), 1340-1346.

Straker, L. Mathiassen. (2009) Increased physical work loads in modern work – a necessity for better health and performance? *Ergonomics*, **52**(10), 1215-1225

Sugimura, H. and Thérault, G. (2010) Impact of supervisor support on work ability in an IT company. *Occupational Medicine*, **60**(6), 451-457.

Sundin, L., Hochwälder, J. and Bildt, C. (2008) A scale for measuring specific job demands within the health care sector: development and psychometric assessment. *International Journal of Nursing Studies*, **45**(6), 914-923.

Syme, S. L. and Berkman, L. F. (1976) Social class, susceptibility and sickness. *American Journal of Epidemiology*, **104**(1), 1-8.

Taris, T. (2006) Bricks without clay: On urban myths in occupational health psychology. *Work and Stress*, **20**(2), 99-104.

Task Force of The European Society of Cardiology and The North American Society of Pacing and Electrophysiology. (1996) Heart rate variability. Standards of measurement, physiological interpretation, and clinical use. *European Heart Journal*, **17**, 354-381.

Tassi, P. and Muzet, A. (2000) Sleep inertia. *Sleep Medicine Reviews*, **4**(4), 341-353.

Tausig, M., Fenwick, R., Sauter, S. L., Murphy, L. R. and Graif, C. (2004) The changing nature of job stress: risks and resources. *Research in Occupational Stress and Wellbeing*, **4**, 93-126.

Taylor, S. E., Seeman, T. E., Eisenberger, N. I., Kozanian, T. A., Moore, A. N. and Moons, W. G. (2010) Effects of a supportive or an unsupportive audience on biological and psychological responses to stress. *Journal of Personality and Social Psychology*, **98**(1), 47-56.

- Thayer, J. F. and Lane, R. D. (2007) The role of vagal function in the risk for cardiovascular disease and mortality. *Biological Psychology*, **74**(2), 224-242.
- Thayer, J. F. and Sternberg, E. (2006) Beyond heart rate variability. *Annals of the New York Academy of Sciences*, **1088**, 361-372.
- Thayer, J. F., Yamamoto, S. S. and Brosschot, J. F. (2010) The relationship between autonomic imbalance, heart rate variability and cardiovascular disease risk factors. *International Journal of Cardiology*, **2**(28), 122-131.
- Therrien, F., Drapeau, V., Lupien, S. J., Beaulieu, S., Dore, J., Tremblay, A. Richard, D. (2008) Awakening cortisol response in relation to psychosocial profile and eating behaviours. *Physiology and Behaviour*, **93**(1-2), 282-288.
- Theorell, T., Perski, A., Askerdt, T., Sigala, F., Ahlberg-Hulten, G., Svensson, J. and Eneroth, P. (1998) Changes in job strain in relation to changes in physiological state. *Scandinavian Journal of work and Environmental Health*, **14**, 189-196.
- Thompson, A. Jones, H., Gregson, W. and Atkinson, G. (2014) Effects of dawn simulation on markers of sleep inertia and post-awakening performance in humans. *European Journal of Applied Physiology*, **114**, 1049-1056.
- Thorn, L., Hucklebridge, F., Evans, P. and Clow, A. (2006) Suspected non-adherence and weekend versus week day differences in the awakening cortisol response. *Psychoneuroendocrinology*, **31**, 1009-1018.
- Thorn, L., Hucklebridge, F., Evancs, P. and Clow, A. (2009) The cortisol awakening response, seasonality, stress and arousal: a study of trait and state influences. *Psychoneuroendocrinology*, **34**(3), 299-306.
- Thorn, L., Hucklebridge, F., Esgate, A., Evans, P. and Clow, A. (2014) The effect of dawn simulation on the cortisol response to awakening in healthy participants. *Psychoneuroendocrinology*, **29**(7) 925-930.
- Tight, M. (2010) Are academics workloads increasing? The post-war survey evidence in the UK. *Higher Educaion Quarterly*, **64**(2), 200-215.
- Torgén, M (2005) Experiences of WAI in a random sample of the Swedish working population. *International Congress Series*, **1280**, 328-332.

Torres, B, D, L, C., Lopez, C. L. And Orellana, J. n. (2008) Analysis of heart rate variability at rest and during aerobic exercise: a study in healthy people and cardiac patients. *British Journal of sports Medicine*, **42**, 715-720.

Totterdell, P., Wood, S. and Wall, T. (2006) An intra-individual test of the demands-control model: a weekly diary study of psychological strain in portfolio workers. *Journal of Occupational Psychology*, **79**(1), 63-84.

Trieber, F. A., Kamarck, T., Schneiderman, N., Sheffield, D., Kapuku, G. and Taylor, T. (2003) Cardiovascular reactivity and development of preclinical and clinical disease states. *Psychosomatic Medicine*, **65**, 46-62.

Tsigos, C. and Chrousos, G. P. (2002) Hypothalamic-pituitary-adrenal axis, neuroendocrine factors and stress, *Journal of Psychosomatic Research*, **53**, 865-871.

Tsuji, H., Larson, M. G., Venditti, F. S., Manders, E. S., Evans, J. C., Feldman, C. L. And Levy, D. (1996) Impact of reduced heart rate variability on risk for cardiac events. The Framington Heart Study. *Circulation*, **94**, 2850-2855.

Tsutsumi, A. and Kawakami, N. (2004) A review of empirical studies on the model of effort-reward imbalance at work: reducing occupational stress by implementing a new theory. *Social Science and Medicine*, **59**, 2335-2359.

Tulppo, M. P., Makikallio, T. H., Takala, T. E., Seppanen, T. and Huikuri, H. V. (1996) Quantitative beat-to-beat analysis of heart rate dynamics during exercise. *Heart and Circulatory Physiology*, **271**, 244-252.

Tulppo, M. P., Mäkikallio, T. H., Seppänen, T., Laukkanen, R. T. and Huikuri, H. V. (1998) Vagal modulation of heart rate during exercise: effects of age and physical fitness. *American Journal of Physiology – Heart and Circulatory Physiology*, **274**, 424-429.

Tuomi, K., Eskelinen, L., Toikkanen, J., Jarvinen, E., Ilmarinen, J. and Klockjars, M. (1991) Work load and individual factors affecting work ability among aging municipal employees. *Scandinavian Journal of Work and Environmental Health*, **17**(suppl 1), 128-134.

Tuomi, K., Ilmarinen, J., Seitsamo, J., Huuhtanen, P., Martikainen, R., Nygård, C. H., Klockars, M. Summary of the Finnish research project (1981-1992) to promote the health and work ability of aging workers. (1997a) *Scandinavian Journal of work and Environmental Health*, **23**(suppl 1), 66-71.

Tuomi, K., Ilmarinen, J., Martikainen, R., Aalto, L. and Klockars, M. (1997b) Aging, work, life-style and work ability among Finish municipal workers in 1982-1992. *Scandinavian Journal of Work and Environmental Health*, **23**(suppl 1), 58-65.

Tuomi, K., Huuhtanen, P., Nykyri, E. and Ilmarinen, J. (2001) Promotion of work ability, the quality of work and retirement. *Occupational Medicine*, **55**(5), 318-324.

Tuomi, K., Vanhala, S., Nykyri, E. and Janhonen, M. (2004) Organizational practices, work demands and the wellbeing of employees: a follow-up study in the metal industry and retail trade. *Occupational Medicine*, **54**, 115-121.

Treiber, F. A., Kamarck, T., Schneiderman, N., Sheffield, D., Kapaku, G. and Taylor, T. (2003) Cardiovascular reactivity and development of preclinical and clinical disease states. *Psychosomatic Medicine*, **65**, 46-62.

Uchino, B. N. and Garvey, T. S. (1997) The availability of social support reduces cardiovascular reactivity to acute psychological stress. *Journal of Behavioural Medicine*, **20**(1), 15-27.

Uchino, B. N., Uno, D., Holt-Lunstad, J. H. and Flinders, J. B. (1999) Age related differences in cardiovascular reactivity during acute psychological stress in men and women. *Journal of Gerontology: Psychological Sciences*, **54**(6), 339-346.

Uchino, B. N. (2006) Social support and health: a review of physiological processes potentially underlying links to disease outcomes. *Journal of Behavioural Medicine*, **29**(4), 377-387.

Uchino, B. N., Carlisle, M., Birmingham, W. and Vaughn, A. A. (2010) Social support and the reactivity hypothesis: Conceptual issues in examining the efficacy of perceived support during acute physiological stress. *Biological Psychology*, **86**(2), 137-142.

Uchino, B. N., Bowen, K., McKenzie, C. and Birmingham, W. (2012) Psychological pathways linking social support to health outcomes: a visit with the “ghosts” of research past, present and future. *Social Science and Medicine*, **74**(7), 949-957.

Ulrich-lai, Y. M. and Herman, J. P. (2009) Neural regulation of endocrine and autonomic stress responses. *Nature Reviews Neuroscience*, **10**, 397-409.

Van Amselsvoort, L. G. P. M., Schouten, E. G., Maan, A. C., Sweenne, C. A. and Kok, F. J. (2000) Occupational determinants of heart rate variability. *International Archives of Occupational Health*, **73**, 255-262.

Van den Berg, T. I. J., Alavinia, S. M., Bredt, F. J., Lindeboom, D., Elders, L. A. M. and Burdorf, A. (2008) The influence of psychosocial factors at work and life style on health and work ability among professional workers. *International Archives of Occupational and Environmental Health*, **81**, 1029-1036.

Van Egeren, L. F. and Sparrow, A. W. (1989) Laboratory stress testing to assess real-life cardiovascular reactivity. *Psychosomatic Medicine*, **51**, 1-9.

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

Van Vegchel, N., de Jonge, J., Bosma, H. and Schaufeli, W. (2005) Reviewing the effort-reward imbalance model: drawing up the balance of 45 empirical studies. *Social Science and Medicine*, **60**, 1117-1131.

Vargas, I., Lopez-Duran, N. (2014) Dissecting the impact of sleep and stress on the cortisol awakening response in young adults. *Psychoneuroendocrinology*, **40**, 10-16.

Verdecchia, P., Porcellati, C., Scillaci, G., Borgioni, C., Ciucci, A., Battistelli, M., Guerrieri, M., Gatteschi, C., Zampi, I., Santucci, A., Santucci, C. and Reboldi, G. (1994). Ambulatory blood pressure. An independent predictor of prognosis in essential hypertension. *Hypertension*, **24**(6), 793-801.

Verrier, W. and Harvey, J. (2010) An investigation into work related stressors on diagnostic radiographers in a local district hospital. *Radiography*, **16**, 115-124.

Virtanen, M., Ferrie, J. E., Singh-Manoux, A., Shipley, M. J., Vahtera, J., Marmot, M. G. and Kivimäki, M (2010) Overtime work and incident coronary heart disease: the Whitehall II prospective cohort study. *European Heart Journal*, **31**(14), 1672-1673.

Vrijkotte, T. G. M., van Doornen, L. J. P. and de Geus, E. J. C. (2000) Effects of work stress on ambulatory blood pressure, heart rate, and heart rate variability. *Hypertension*, **35**, 880-886.

Wagner, U., Fischer, S., Born, J. (2002) Changes in emotional response to aversive pictures across periods rich in slow-wave sleep versus rapid eye movement sleep. *Psychosomatic Medicine*, **64**, 627-634.

Wager, N., Fieldman, G. and Hussey, T. (2003). The effect on ambulatory blood pressure of working under favourably and unfavourably perceived supervisors. *Occupational and Environmental Medicine*, **60**, 468-474.

Waldenström, K. and Härenstam, A. (2008) Does the demand-control model correspond to externally assessed demands and control for both women and men? *Scandinavian Journal of Public Health*, **36**, 242-249.

Wall, T. D., Jackson, P. R., Mullarkey, S. and Parker, S. K. (1996) The demands-control model of job strain: a more specific test. *Journal of Occupational and Organizational Psychology*, **69**:153–66.

Webster M. J. I. and Glaser, R. (2008) Stress hormones and immune function. *Cellular Immunology*, **252**, 16-26.

Whitsel, E. A., Raghunathan, T. E., Pearce, R. M., Lin, D., Rautaharju, P. M., Lemaitre, R. and Siscouick, D. S. (2001) RR-interval variation, the QT interval index and risk of primary cardiac arrest among patients without clinically recognised heart disease. *European Heart Journal*, **22**, 165-173.

Wilhelm, I., Born, J., Kudielka, B. M., Schlotz, W. and Wüst, S. (2007) Is the cortisol awakening rise a response to awakening? *Psychoneuroendocrinology*, **32**, 358-366.

Williams, E., Magid, K. and Steptoe, A. (2004) The impact of time of waking and concurrent subjective stress on the cortisol response to awakening. *Psychoneuroendocrinology*, **30**(2), 139-148.

Williams, E., Magid, K. and Steptoe, A. (2005) The impact of time of waking and concurrent subjective stress on the cortisol response to awakening. *Psychoneuroendocrinology*, **50**, 139-148.

Winefield, A. H. and Jarrett, R. J. (2001). Occupational stress in university staff. *International Journal of Stress Management*, **8**, 285–298.

Winefield, A. H., Gillespie, N., Stough, C., Dua, J., Hapuarachchi, J. and Boyd, C. (2003) Occupational stress in Australian university staff: Results from a national survey. *International Journal of Stress Management*, **10**(1), 51-63.

Winter, R., Taylor, T. and Sarros, J. (2000) Trouble at Mill: quality of academic worklife issues within a comprehensive Australian university. *Studies in Higher Education*, **25**(3), 279-294.

Wolf-Maier, K., Cooper, R. S., Banegas, J. R., Giampaoli, S., Hense, H-W., Joffres, M., Kastarinen, M., Poulter, N., Primastesta, P., Rodríguez-Artalejo, F., Stegmayr, B., Thamm, M., Tuomilehto, J., Vanuzzo, D. and Vescio, F. (2003) Hypertension prevalence and blood pressure levels in 6 European countries, Canada, and the United States. *The Journal of the American Medical Association*, **289**(18), 2363-2369.

Wu, T., Snieder, H. and de Geus, E. (2009) Genetic influences on cardiovascular stress reactivity. *Neuroscience and Behavioural Reviews*, **35**(1), 58-68.

Wüst, S., Federenko, I., Hellhammer, D. H. and Kirschbaum, C. (2000a). Genetic factors, perceived chronic stress, and the free cortisol response to awakening. *Psychoneuroendocrinology*, **25**, 707-720.

Wüst, S., Wolf, J., Hellhammer, D. H., Federenko, I., Schommer, N. and Kirschbaum, C. (2000b). The cortisol awakening response – normal values and confounds. *Noise and Health*, **2**(7), 79-88.

Wüst, S., Federenko, I. S., Van Rossum, E. F.C., Koper, J. W., Kumsta, R., Entringer, S. and Hellhammer, D. H. (2006) A psychobiological perspective on

genetic determinants of hypothalamus-pituitary-adrenal axis activity. *Annals of the New York Academy of Sciences*, **1032**, 52-62.

Yamamoto, Y., Hughson, R. L. and Peterson, J. C. (1991) Autonomic control of heart rate during exercise studied by heart rate variability spectral analysis. *Journal of Applied Physiology*, **71**, 1136 – 1142.

Yamamoto, Y., Hughson, R. L. and Nakamura, Y. (1992) Autonomic nervous system responses to exercise in relation to ventilatory threshold. *Chest* **101**: 206–210.

Young, E. A., Abelson, J. L. and Cameron, O. G. (2005) Interaction of brain noradrenergic system and the hypothalamic-pituitary-adrenal (HPA) axis in man. *Psychoneuroendocrinology*, **30**(8), 807-814.

Zhang, J. (2007) Effect of age and sex on heart rate variability in healthy subjects. *Journal of Manipulative Physiological Therapy*, **30**, 374-379.

Zhang, J., Ma, R. C. W., Kong, A. P. S., So, W. Y., Li, A. M., Lam, S. P., Li, S. X., Yu, M. W. M., Ho, C. S., Chan, M. H. M., Zhang, B. and Wing, Y. K. (2011) Relationship of sleep quantity and quality with 24-hour urinary catecholamines and salivary awakening cortisol in healthy middle-aged adults. *Sleep*, **34**(2) 225-233.

Zohar, D., Tzischinski, O. and Epstein, R. (2003) Effects of energy availability on immediate and delayed emotional reactions to work events. *Journal of Applied Psychology*, **88**, 1082-1093.

Appendices

APPENDIX I – APPLICATION TO ETHICS COMMITTEE (STUDY ONE)

Edinburgh Napier University Faculty of Health, Life & Social Sciences Research Ethics and Governance Committee Application Form for Project Approval

This application form must be completed by all Edinburgh Napier staff and students conducting research which involves the gathering and processing of primary data concerning human participants, and where the outcomes will be disseminated beyond the individual who originally collected or processed the information. Researchers/institutions external to Edinburgh Napier should complete and submit the relevant sections of this application form and, if already obtained, submit the letter of approval to proceed with this project (with a copy of the application form) provided by another Research Ethics and Governance Committee.

Exceptions: (1) research involving NHS staff or patients, or therapeutic interventions in healthy normal populations are covered by separate arrangements: in these cases, the relevant NHS Ethics Application form should be submitted to the FHLSS Research Ethics and Governance Committee before submission to the NHS Research Ethics Committee; (2) research concerning non-human animals and environmental issues is covered by separate arrangements, in accordance with relevant Home Office regulations; (3) research which involves the analysis of documents or material in non-print media which are freely available for public access does NOT need Research Ethics and Governance Committee approval.

SECTION ONE: GENERAL

1. Applicant (*All correspondence will be sent to the details you provide below*)

Full Name and Title: Mr Thomas George Campbell

School (if applicable): Life Sciences

Postal Address (work or home):

Email Address: 06016111@live.napier.ac.uk

Contact Telephone Number:

Affiliation (please tick): Edinburgh Napier Staff

Edinburgh Napier Student (fill out details below)

Matriculation Number: 06016111

Name of Programme:

Level of Study: UG1 UG2 UG3 UG4

MA/MSc MPhil/PhD

Non-Edinburgh Napier external applicant
(Please include a copy of any existing application form and letter of approval for this project from a Research Ethics and Governance Committee.)

2. Title of research project: Towards a more objective assessment of work ability

3. Start and end dates of research project: 1/11/09 – 1/11/10

4. Details (amount and source) of any financial support from outside Edinburgh Napier University.

None

If you are a **Non-Edinburgh Napier external applicant** and have included a copy of your home institution ethics application form, along with the letter of approval please go to **Section 4**.

5. Other researchers involved, together with role (e.g. PI / Director of Studies/ Supervisor) and affiliation (e.g. School of Health and Social Sciences, Edinburgh Napier University)

Director of Studies: Prof. Richard Davison

Supervisor: Dr Geraint Florida-James

6. Name of Independent Advisor

Shona Irvine

SECTION 2: DETAILS OF PROJECT

7. Aims and research questions of the project

Aims:

- To devise a method to objectively assess and quantify the physical and psychological demands of specific jobs.
- To assess the ability of workers to cope with the specific demands of the job based upon physiological responses.
- To amalgamate objective measures pertaining to the specific demands of a job, and questionnaire responses, into a more comprehensive and accurate tool for the assessment of work ability, or quality of working life, than is currently available

Research Question:

- Is it possible to increase the accuracy with which work ability or quality of working life can be assessed by incorporating objective data into an assessment tool?

8. Background of research project

In the United Kingdom, which already has one of the highest rates of employment amongst 55 to 64 year olds in Europe (Ilmarinen, 2006), the state pension age for both men and women is set to increase further (Directgov, 2009). Given this increase in the age of workers there is a greater requirement to understand the demands, both physical and psychological, of specific jobs to ensure that employees can cope with these demands. Additionally there is a legal requirement for all employers to conduct regular stress audits of all staff. One of the most commonly used tools for the assessment of the ability of workers to meet the demands of their job is the workability index (WAI), devised by the Finish Institute of Occupational Health. The WAI is based upon the demand-control model (Karasek, 1979) and combines an individual's subjective experience of the physical and psychosocial demands of work and their ability to meet these

demands, with information regarding health status, functioning and sick leave report. Whilst the simplicity of the WAI may be attractive to employers, the very basic and subjective interpretation of the demands of a job being either physical or psychological may well limit its accuracy. Whilst other assessment tools such as the work related quality of life scale (QoWL Ltd, 2008) give greater consideration to variables that exist out with the workplace, stress at work and working conditions are still pertinent factors. Despite this there is there no objective assessment of work place stress involved. Incorporating an objective assessment of the levels of work strain into an assessment tool, by measuring the physiological responses of the cardiovascular and endocrine systems to the demands of work, should therefore increase the accuracy with which work ability can be measured. Furthermore, by objectively determining the extent to which both physical, and psychological, stressors contribute to the overall demand of a particular job, it should be possible to improve the accuracy of questionnaires to determine work ability or work related quality of life.

9. Brief outline of project and study method

Methodology / data collection

All participants will be required to attend a short familiarization session where they will be exposed to all of the instrumentation that will be used in this study. Additionally, at this stage anthropomorphic measurements will be obtained and participants will be given three short questionnaires to complete; the work related quality of life scale (QoWL Ltd, 2008), the workability index (Finish Institute of Occupational Health, 2006) and the general practice physical activity questionnaire (Dept of Health, 2006). Objective assessments will be collected over the course of 2 working days, and 1 weekend day in the case of salivary cortisol. Participants will be simultaneously instrumented with an ambulatory blood pressure monitor, validated by the British Hypertension Society and an Actiheart® monitor

Ambulatory blood pressure monitor - The pressure cuff will be attached to the non-dominant arm and a mercury sphygmomanometer will be used to ensure readings are calibrated to within 5mmHg of the mercury readings, in accordance with The American Heart Association recommendations (Pickering *et al*, 2005). The monitor will be set to obtain a blood pressure measurement every 30 minutes and will be worn for the duration of the working day. The participants will be instructed to keep their arm motionless by their side whilst the monitor is obtaining a reading. Once the cuff has deflated the participants will be required to record in a diary what they had been doing in the period immediately prior to the measurement.

Actiheart® monitor - Prior to application of the electrodes, the skin area will be cleaned and the top layer of skin removed using an electrode skin preparation pad. The participants will then be required to wear the Actiheart for 30 minutes during which time they are required to move around as they might in the execution of their daily work. The signal integrity will then be checked and a test recording made. The Actiheart monitor will be used in short term mode to facilitate collection of data regarding HR, physical activity, energy expenditure and Interbeat Interval (allowing for analysis of HRV).

Salivary Cortisol – Participants will be provided with 6 plastic vials for the collection of saliva samples. These samples will be obtained immediately upon waking and then 30 minutes later, upon the 2 working days during which other measurements are being taken and on one weekend or non-working day. The

participants will record the date and time of the samples upon the label on the outside of the vial. The samples obtained during working days will be collected from the participants and frozen immediately upon their arrival at work. Participants will be required to store the non-working day sample in their own freezer until the next working day. The samples will be analysed using a salivary assay kit (Salimetrics Europe Ltd, Newmarket, UK).

Data Analysis: Data will be analysed using SPSS software to determine whether there are any differences in physiological variables between the two groups. Additionally, regression analysis will be performed on the physiological variables to determine whether any expected correlations between variables exist. It would be anticipated, for instance, that there would be a correlation between HR and BP given the nature of cardiovascular functioning. This is important when it comes to devising a scoring system for the extent of the physical and psychological demands in order to avoid overestimating they may have upon work ability. Mean group data obtained from the objective measures will be used to determine an overall job demand score for both groups. This will be done by comparing the scores for each variable with normative data where this exists ie (ABP, HR, HRV, BP, energy output) and allocating them each a score of 1 to 5 depending on how they compare. These individual scores will then be used to determine the overall job demand with consideration being given to the interaction between variables assessing similar cardiovascular and endocrine responses. The psychological demands for each job will be quantified by looking at salivary cortisol data and additionally at BP, HR and HRV where response to physical activity has been factored out. The physical demands of each job will be assessed by considering the physical activity data, energy expenditure, BP, HR and HRV where the last 3 variables correspond to variance in levels of physical activity. The ability of individuals to cope with these demands will then be determined by plotting a normal distribution and then allocating cut off points to differentiate between normal, borderline and high risk. Consideration will then need to be given to the actual demands of the job. The responses to the questionnaires will be initially used to correlate the original WAI and WRQoL with the subjective data and also with number of sick days. The same will then be done using the revised weighting for the physical / psychological demands of the respective job.

SECTION 3: PARTICIPANTS

Please attach copies of the following, together with any further supporting documentation, as indicated below:

- *Participant information sheet outlining the nature of the research*
- *Participant consent form*
- *Summary of debriefing (if applicable)*

10. Nature and number of participants

Indicate which participant groups will take part in the research and indicate the total numbers of participants, where applicable.

	YES please state number	NO	N / A
Edinburgh Napier University students		X	
Edinburgh Napier University Staff	< 100		
Members of the public		X	
Clinical population*		X	
People with mental health issues*		X	
People in custody*		X	
Children (under 18 years)*		X	
People with learning or communication difficulties*		X	
People engaged in illegal activities (e.g. drug-taking)*		X	
Other (please specify):*		X	

* if you have answered Yes to any of the starred items you should tick Q.15 box B to indicate that there may be ethical implications with possible additional legal procedures attached to them.

11. Inclusion and exclusion criteria

Inclusion:

- Participants must be employed by Edinburgh Napier University as either academic or facilities services staff.
- Participants must be working a minimum of 20 hours per week.

Exclusion

- Smoking, alcohol consumption in excess of weekly recommended limits of 21 units and 14 units for males and females respectively, use of medication which could affect blood pressure or heart rate dynamics, or having a diagnosed medical condition which could affect cardiovascular or respiratory function

12. Recruitment of participants

Explain recruitment methods employed (e.g. in person, emails, posters: please attach copies)

A brief outline of the study will be communicated to Edinburgh Napier staff via the staff intranet and a global email to employees working within the relevant departments along with a request for volunteers. Participants meeting the inclusion criteria will then be provided with an information sheet and consent form.

13. Consent and care of participants

Tick as appropriate

		YES	NO	N/A
--	--	-----	----	-----

a	Will you describe the main procedures to participants in advance so that they are informed about what to expect in your study?	X		
b	Will you tell participants that their participation is voluntary?	X		
c	Will you obtain written informed consent for participation?	X		
d	If the research is observational (including tape and video), will you ask participants for their consent to being observed?			X
e	Will you tell participants that they may withdraw from the research at any time without penalty and for any reason?	X		
f	If using questionnaires or interviews, will you give participants the option of omitting questions they do not want to answer without penalty?	X		
g	Will confidentiality be agreed (i.e. that participants will not be identifiable in any records, presentations or reports (oral or written) of the research)?	X		
h	Will you tell participants that their data will be treated with full confidentiality and that, if published, it will not be identifiable as theirs?	X		
i	Will you give participants a brief explanation of the purpose of the study at the end of their participation in it, and answer any questions?	X		
j	Will any payment or reward be made to participants, beyond reimbursement of out-of-pocket expenses?		X	
k	Will your project involve deliberately misleading participants in any way?		X	
l	Is the information gathered from participants of a sensitive or personal nature?	X		
m	Is there any realistic risk of any participants experiencing either physical or psychological distress or discomfort?		X	

NB: 1) if you have answered “no” to questions a – i, please tick box Q.15 box B to indicate that there may be ethical implications.

2) if you have answered “yes” to j, k, l or m above, please provide details below (continue on a separate sheet if necessary), and state what you will advise participants to do if they should experience any problems (e.g. whom they can contact for help).

APPENDIX II – APPLICATION TO ETHICS COMMITTEE (STUDY TWO)

Edinburgh Napier University

Faculty of Health, Life & Social Sciences
Research Ethics and Governance Committee
Application Form for Project Approval

This application form must be completed by all Edinburgh Napier staff and students conducting research which involves the gathering and processing of primary data concerning human participants, and where the outcomes will be disseminated beyond the individual who originally collected or processed the information. Researchers/institutions external to Edinburgh Napier should complete and submit the relevant sections of this application form and, if already obtained, submit the letter of approval to proceed with this project (with a copy of the application form) provided by another Research Ethics and Governance Committee.

Exceptions: (1) research involving NHS staff or patients, or therapeutic interventions in healthy normal populations are covered by separate arrangements: in these cases, the relevant NHS Ethics Application form should be submitted to the FHLSS Research Ethics and Governance Committee before submission to the NHS Research Ethics Committee; (2) research concerning non-human animals and environmental issues is covered by separate arrangements, in accordance with relevant Home Office regulations; (3) research which involves the analysis of documents or material in non-print media which are freely available for public access does NOT need Research Ethics and Governance Committee approval.

SECTION ONE: GENERAL

1. Applicant (*All correspondence will be sent to the details you provide below*)

Full Name and Title: Tom Campbell

School (if applicable): Life Sciences

Postal Address (work or home):

Email Address: T.Campbell@napier.ac.uk

Contact Telephone Number: 0131 455 2365

Affiliation (please tick): Edinburgh Napier Staff

Edinburgh Napier Student (fill out details below)

Matriculation Number: 06016111

Name of Programme:

Level of Study: PhD

Non-Edinburgh Napier external applicant
(Please include a copy of any existing application form and letter of approval for this project from a Research Ethics and Governance Committee.)

2. Title of research project

A single subject investigation of temporal variation in heart rate variability and the cortisol awakening response with respect to acute work-related factors.

3. Start and end dates of research project 6/1/12 – 6/2/12

4. Details (amount and source) of any financial support from outside Edinburgh Napier University. NONE

If you are a **Non-Edinburgh Napier external applicant** and have included a copy of your home institution ethics application form, along with the letter of approval please go to **Section 4**.

5. Other researchers involved, together with role (e.g. PI / Director of Studies/ Supervisor) and affiliation (e.g. School of Nursing, Midwifery & Social Care and School of Life Sciences, Edinburgh Napier University)

Dr Geraint Florida-James

Dr Tony Westbury

Mrs. Shona Irvine

6. Name of Independent Advisor (where applicable)

SECTION 2: DETAILS OF PROJECT

Supporting documentation should be attached where detailed below.

7. Aims and research questions of the project (maximum 5)

To investigate the intra-individuality of both long-term heart rate variability and the awakening cortisol response and the association between them.

8. Background of research project (300 words maximum). References should be cited and listed.

9. Brief outline of project and study method (approx 500 words)

Actiheart® monitor - Prior to application of the electrodes, the skin area will be cleaned and the top layer of skin removed using an electrode skin preparation pad. The participant will then be required to wear the Actiheart for 30 minutes during which time they are required to move around as they might in the execution of their daily work. The signal integrity will then be checked and a test recording made. The Actiheart monitor will be used in short term mode to facilitate collection of data regarding HR, physical activity, energy expenditure and Interbeat Interval (allowing for analysis of HRV).

Salivary Cortisol – Participants will be provided with 6 plastic vials for the collection of saliva samples. These samples will be obtained immediately upon waking and then 30 minutes later, upon the 2 working days during which other measurements are being taken and on one weekend or non-working day. The participants will record the date and time of the samples upon the label on the outside of the vial. The samples obtained during working days will be collected from the participants and frozen immediately upon their arrival at work. Participants will be required to store the non-working day sample in their own

freezer until the next working day. The samples will be analysed using a salivary assay kit (Salimetrics Europe Ltd, Newmarket, UK).

SECTION 3: PARTICIPANTS

Please attach copies of the following, together with any further supporting documentation, as indicated below:

- Participant information sheet outlining the nature of the research
- Participant consent form
- Summary of debriefing (if applicable)

10. Nature and number of participants

Indicate which participant groups will take part in the research and indicate the total numbers of participants, where applicable.

	YES please state number	NO	N / A
Edinburgh Napier University students		X	
Edinburgh Napier University Staff	1		
Members of the public		X	
Clinical population*		X	
People with mental health issues*		X	
People in custody*		X	
Children (under 18 years)*		X	
People with learning or communication		X	
People engaged in illegal activities (e.g.		X	
Other (please specify):*		X	

* if you have answered Yes to any of the starred items you should tick Q.15 box B to indicate that there may be ethical implications with possible additional legal procedures attached to them.

11. Inclusion and exclusion criteria

Indicate what criteria will be used to select/exclude participants

The only participant in the study will be the primary researcher

12. Recruitment of participants

Explain recruitment methods employed (e.g. in person, emails, posters: please attach copies)

N/A

13. Consent and care of participants

Tick as appropriate

		YES	NO	N/A
a	Will you describe the main procedures to participants in advance so that they are informed about what to expect in your study?			x
b	Will you tell participants that their participation is voluntary?			x
c	Will you obtain written informed consent for participation?			x
d	If the research is observational (including tape and video), will you ask participants for their consent to being observed?			x
e	Will you tell participants that they may withdraw from the research at any time without penalty and for any reason?			x
f	If using questionnaires or interviews, will you give participants the option of omitting questions they do not want to answer without penalty?			x
g	Will confidentiality be agreed (i.e. that participants will not be identifiable in any records, presentations or reports (oral or written) of the research)?			x
h	Will you tell participants that their data will be treated with full confidentiality and that, if published, it will not be identifiable as theirs?			x
i	Will you give participants a brief explanation of the purpose of the study at the end of their participation in it, and answer any questions?			x
j	Will any payment or reward be made to participants, beyond reimbursement of out-of-pocket expenses?			x
k	Will your project involve deliberately misleading participants in any way?			x
l	Is the information gathered from participants of a sensitive or personal nature?			x
m	Is there any realistic risk of any participants experiencing either physical or psychological distress or discomfort?			x

NB: 1) if you have answered “no” to questions a – i, please tick box Q.15 box B to indicate that there may be ethical implications.

2) if you have answered “yes” to j, k, l or m above, please provide details below (continue on a separate sheet if necessary), and state what you will advise participants to do if they should experience any problems (e.g. whom they can contact for help).

APPENDIX III – THE WORK ABILITY INDEX

WORK ABILITY INDEX

1. Current work ability compared with lifetime best.

Assume that your work ability at its best has a value of 10 points. How many points would you give your current work ability? (0 means that you cannot currently work at all)

0 1 2 3 4 5 6 7 8 9 10

2. Work ability in relation to the demands of the job

How do you rate your current work ability with respect to the **physical** demands of your work?

very good 5
rather good..... 4
moderate.....3
rather poor.....2
very poor.....1

How do you rate your current work ability with respect to the **mental** demands of your work?

very good 5
rather good..... 4
moderate.....3
rather poor.....2
very poor.....1

3. Current medical conditions

In the following list, mark your diseases or injuries. Also indicate whether you have been prescribed treatment for the condition. For each condition there may be 2, 1, or no alternatives circled.

	Own Opinion	YES Treatment Prescribed
Injury from accident2		1
01 back2		1
02 arm/hand2		1
03 Leg/foot.....2		1
04 Other part of body, where and what kind of injury?..2		1

YES
Own Treatment
opinion prescribed

Musculoskeletal disease

05 disorder of the upper back or cervical spine, repeated instances of pain.....2	1
06 disorder of the lower back repeated instances of pain....2	1
07 (sciatica) pain radiating from back of leg.....2	1
08 musculoskeletal disorder affecting the limbs (hands, feet) repeated instances of pain.....2	1
09 rheumatoid arthritis.....2	1
10 other musculoskeletal condition, provide detail.....2	1

Cardiovascular disease

11 hypertension (high blood pressure)2	1
12 coronary heart disease, chest pains during exercise2	1
13 coronary thrombosis.....2	1
14 cardiac insufficiency.....2	1
15 other cardiovascular disease, provide detail?.....2	1

Respiratory Disease

16 repeated infections of the respiratory tract (also tonsillitis, acute sinusitis, acute bronchitis)..2	1
17 chronic bronchitis.....2	1
18 chronic sinusitis.....2	1
19 bronchial asthma.....2	1
20 emphysema.....2	1
21 pulmonary tuberculosis.....2	1
22 other respiratory disease, please detail.....2	1

	YES			YES	
	Own	Treatment		Own	Treatment
	opinion	prescribed		opinion	prescribed
Mental disorder					
23			mental disease or severe mental Health problem (for example, severe depression, mental disturbance).....2	1	
24			slight mental disorder or problem (for example, slight depression, tension, anxiety, insomnia....2	1	
Neurological and sensory conditions					
25			problems or injury to hearing..2	1	
26			visual disease or injury (other than refractive error)....2	1	
27			neurological disease (for example, stroke, neuralgia, migraine,2	1	
28			other neurological or sensory disease, provide detail.....2	1	
<hr/>					
Digestive disease					
29			gall stones or disease.....2	1	
30			liver or pancreatic disease.....2	1	
31			gastric or duodenal ulcer.....2	1	
32			gastric or duodenal irritation...2	1	
33			colonic irritation, colitis2	1	
34			other digestive disease, provide detail.....2	1	
<hr/>					
Genitourinary disease					
35			urinary tract infection.....2	1	
36			kidney disease.....2	1	
37			genital disease (for example fallopian tube infection in women or prostatic infection in men...2	1	
38			other genitourinary disease, what?.....2	1	
<hr/>					
skin disease					
39			allergic rash / eczema.....2	1	
40			other rash, what?.....2	1	
41			other skin disease, what?..2	1	
<hr/>					
Tumour					
42			benign tumour.....2	1	
43			malignant tumour (cancer), where?.....2	1	
<hr/>					
Endocrine and metabolic diseases					
44			obesity.....2	1	
45			diabetes.....2	1	
46			goiter or other thyroid disease.2	1	
47			other endocrine or metabolic disease, what?.....2	1	
<hr/>					
Blood diseases					
48			anaemia.....2	1	
49			other blood disorder.....2	1	
<hr/>					
Birth defects					
50			birth defect, what.....2	1	
<hr/>					
Other disorder or disease					
51			what?.....2	1	
<hr/>					

4. Estimated work impairment due to diseases

Is your illness or injury a hindrance to your current job? Circle more than one alternative if needed.

There is no hindrance / I have no diseases.....6

I am able to do my job, but it causes some symptoms.....5

I must sometimes slow down my work pace or change my work methods.....4

Because of my disease, I feel I am able to do only part time work.....2

In my opinion, I am entirely unable to work.....1

5. Sick leave during the past year (12 months)

How many whole days have you been off work because of a health problem (disease or health care or for examination) during the past (12 months)?

none at all.....5
 at the most 9 days.....4
 10 – 24 days.....3
 25 - 99 days.....2
 100 – 365 days.....1

6. Own prognosis of work ability two years

from now

Do you believe that, from the standpoint of your health, you will be able to do your current job **two years from now?**

unlikely.....1
 not certain.....4
 relatively certain.....7

7. Mental resources

Have you recently been able to enjoy your regular daily activities?

often.....4
 rather often.....3
 sometimes.....2
 rather seldom.....1
 never.....0

Have you recently been active and alert?

often.....4
 rather often.....3
 sometimes.....2
 rather seldom.....1
 never.....0

Have you recently felt yourself to be full of hope for the future?

continuously.....4
 rather often.....3
 sometimes.....2
 rather seldom.....1
 never.....0

APPENDIX IV – HSE MANAGEMENT STANDARDS INDICATOR TOOL

Instructions: It is recognised that working conditions affect worker well-being. Your responses to the questions below will help us determine our working conditions now, and enable us to monitor future improvements. In order for us to compare the current situation with past or future situations, it is important that your responses reflect your work in the last six months

		Never	Seldom	Sometimes	Often	Always
1	I am clear what is expected of me at work	1	2	3	4	5
2	I can decide when to take a break	Never 1	Seldom 2	Sometimes 3	Often 4	Always 5
3	Different groups at work demand things from me that are hard to combine	Never 5	Seldom 4	Sometimes 3	Often 2	Always 1
4	I know how to go about getting my job done	Never 1	Seldom 2	Sometimes 3	Often 4	Always 5
5	I am subject to personal harassment in the form of unkind words or behaviour	Never 5	Seldom 4	Sometimes 3	Often 2	Always 1
6	I have unachievable deadlines	Never 5	Seldom 4	Sometimes 3	Often 2	Always 1
7	If work gets difficult, my colleagues will help me	Never 1	Seldom 2	Sometimes 3	Often 4	Always 5
8	I am given supportive feedback on the work I do	Never 1	Seldom 2	Sometimes 3	Often 4	Always 5
9	I have to work very intensively	Never 5	Seldom 4	Sometimes 3	Often 2	Always 1
10	I have a say in my own work speed	Never 1	Seldom 2	Sometimes 3	Often 4	Always 5
11	I am clear what my duties and responsibilities are	Never 1	Seldom 2	Sometimes 3	Often 4	Always 5
12	I have to neglect some tasks because I have too much to do	Never 5	Seldom 4	Sometimes 3	Often 2	Always 1
		Never	Seldom	Sometimes	Often	Always

13	I am clear about the goals and objectives for my department	1	2	3	4	5
14	There is friction or anger between colleagues	Never 5	Seldom 4	Sometimes 3	Often 2	Always 1
15	I have a choice in deciding how I do my work	Never 1	Seldom 2	Sometimes 3	Often 4	Always 5
16	I am unable to take sufficient breaks	Never 1	Seldom 2	Sometimes 3	Often 4	Always 5
17	I understand how my work fits into the overall aim of the organisation	Never 1	Seldom 2	Sometimes 3	Often 4	Always 5
18	I am pressured to work long hours	Never 1	Seldom 2	Sometimes 3	Often 4	Always 5
19	I have a choice in deciding what I do at work	Never 1	Seldom 2	Sometimes 3	Often 4	Always 5
20	I have to work very fast	Never 1	Seldom 2	Sometimes 3	Often 4	Always 5
21	I am subject to bullying at work	Never 1	Seldom 2	Sometimes 3	Often 4	Always 5
22	I have unrealistic time pressures	Never 1	Seldom 2	Sometimes 3	Often 4	Always 5
23	I can rely on my line manager to help me out with a work problem	Never 1	Seldom 2	Sometimes 3	Often 4	Always 5
24	I get help and support I need from colleagues	Never 1	Seldom 2	Sometimes 3	Often 4	Always 5
25	I have some say over the way I work	Never 1	Seldom 2	Sometimes 3	Often 4	Always 5
26	I have sufficient opportunities to question managers about change at work	Never 1	Seldom 2	Sometimes 3	Often 4	Always 5
27	I receive the respect at work I deserve from my colleagues	Never 1	Seldom 2	Sometimes 3	Often 4	Always 5
28	Staff are always consulted about change at work	Never 1	Seldom 2	Sometimes 3	Often 4	Always 5
29	I can talk to my line manager about something that has upset or annoyed me about work	Never 1	Seldom 2	Sometimes 3	Often 4	Always 5
		Never	Seldom	Sometimes	Often	Always

30	My working time can be flexible	1	2	3	4	5
31	My colleagues are willing to listen to my work-related problems	Never 1	Seldom 2	Sometimes 3	Often 4	Always 5
32	When changes are made at work, I am clear how they will work out in practice	Never 1	Seldom 2	Sometimes 3	Often 4	Always 5
33	I am supported through emotionally demanding work	Never 1	Seldom 2	Sometimes 3	Often 4	Always 5
34	Relationships at work are strained	Never 1	Seldom 2	Sometimes 3	Often 4	Always 5
35	My line manager encourages me at work	Never 1	Seldom 2	Sometimes 3	Often 4	Always 5

Thank you for completing the questionnaire.

APPENDIX V - POSITIVE AND NEGATIVE AFFECT SCHEDULE (SHORT VERSION)

PANAS Questionnaire:

This scale consists of a number of words that describe different feelings and emotions. Read each item and then list the number from the scale below next to each word. Indicate to what extent you feel this way right now, that is, at the present moment.

1	2	3	4	5
Very slightly	A Little	Moderately	Quite a Bit	Extremely
Or not at all				

- | | | | |
|-----------|--------------|-----------|------------|
| _____ 1. | Interested | _____ 11. | Irritable |
| _____ 2. | Distressed | _____ 12. | Alert |
| _____ 3. | Excited | _____ 13. | Ashamed |
| _____ 4. | Upset | _____ 14. | Inspired |
| _____ 5. | Strong | _____ 15. | Nervous |
| _____ 6. | Guilty | _____ 16. | Determined |
| _____ 7. | Scared | _____ 17. | Attentive |
| _____ 8. | Hostile | _____ 18. | Jittery |
| _____ 9. | Enthusiastic | _____ 19. | Active |
| _____ 10. | Proud | _____ 20. | Afraid |

Scoring Instructions:

Positive Affect Score: Add the scores on items 1, 3, 5, 9, 10, 12, 14, 16, 17, and 19. Scores can range from 10 – 50, with higher scores representing higher levels of positive affect. Mean Scores: Momentary = 29.7 (SD = 7.9); Weekly = 33.3 (SD = 7.2)

Negative Affect Score: Add the scores on items 2, 4, 6, 7, 8, 11, 13, 15, 18, and 20. Scores can range from 10 – 50, with lower scores representing lower levels of negative affect. Mean Score: Momentary = 14.8 (SD = 5.4); Weekly = 17.4 (SD = 6.2)

APPENDIX VI – VISUAL ANALOGUE SCALE (ACUTE DEMAND)

Participant ID_____

Date_____

How demanding was your day compared to an average working day? Place a vertical mark on the line below to indicate How demanding you feel your working day has been.

Not at all demanding



Very demanding

APENDIX VII – DAILY WORKLOAD

At the present moment to what extent do the following apply, where 1 represents not at all and 5 represents very much?

Circle the appropriate number

- | | | | | | |
|-------------------------------------------------|---|---|---|---|---|
| Do you:-Have to work fast? | 1 | 2 | 3 | 4 | 5 |
| • Have too much work to do? | 1 | 2 | 3 | 4 | 5 |
| • Have to work extra hard to complete a task? | 1 | 2 | 3 | 4 | 5 |
| • Feel under time pressure? | 1 | 2 | 3 | 4 | 5 |
| • Have to deal with a backlog? | 1 | 2 | 3 | 4 | 5 |
| • Have problems with the pace you must work at? | 1 | 2 | 3 | 4 | 5 |
| • Have problems with the workload? | 1 | 2 | 3 | 4 | 5 |
| • And can you do your work in comfort? | 1 | 2 | 3 | 4 | 5 |

Date:

Time: