Anticipation and the cortisol awakening response within a dynamic psychosocial work environment

Abstract

The cortisol awakening response (CAR) is a distinct element of the diurnal pattern of cortisol release, believed to be partly driven by the anticipation of the demands of the upcoming day. Although evidence suggests that the response may be associated with various ergonomic factors, the influence of temporal variation in anticipated workplace characteristics upon the CAR remains unclear. The current study examined the CAR on two work days of differing levels of anticipatory demand (high/low) and a single weekend day through repeated assessment of healthy employees (N=15). Participants provided saliva samples immediately upon awakening and thirty minutes thereafter on all assessment days. A paired t-test confirmed that the two work days differed significantly in terms of perceived acute demand and a repeated measures ANOVA revealed a significant main time effect, confirming a rise in salivary cortisol over the post-awakening period. This response differed according to the nature of assessment day, being greater on the "high" compared to the "low" demand day, or the weekend. These findings suggest the CAR is influenced by the perceived level of acute anticipatory work-related demand of the assessment day, highlighting the importance of attending to the dynamics of the environment when employing real-world assessments.

Keywords: acute work demands; ambulatory assessment; cortisol awakening response; employee well-being; psychosocial stress.

Introduction

The modern workplace is commonly characterized by demands of a mental and emotional nature and a growing body of evidence demonstrates that exposure to work-related psychosocial strain can lead to impairment of both psychological and physical health. As a result workplace risk assessments are no longer exclusively concerned with the physical environment and are increasingly incorporating measures of psychosocial hazard. However, the presence of psychosocial hazard may not necessarily lead to harm; biopsychosocial analysis of challenge and threat motivation has shown that an individual's appraisal of a performance environment determines their physiological response (Blascovich & Mendes, 2000). Furthermore, individual characteristics including; hardiness, coping (Powell & Schlotz, 2012), optimism, dispositional affect (Lai et al., 2005) personality (Tykra et al., 2006) and trait anxiety (Therrien *et al.*, 2008) have been shown to be related to stress reactivity. As a result, it has been argued that ambulatory assessments of work-related well-being should be added to traditional approaches in order to understand the psychophysiological responses to the work environment (Eller, Netterstrøm, & Hansen, 2006; Hanson, Godaert, Maas, & Meijman, 2001; Johnston, Jones, Charles, McCann, & McKee, 2013).

The cortisol awakening response (CAR) is a distinct element of the diurnal pattern of cortisol release (Clow, Thorn, Evans, & Hucklebridge, 2004; Fries, Dettenborn, & Kirschbaum, 2009; Powell & Schlotz, 2012) which is believed to represent a response to the reactivation of memory upon waking (Wilhelm, Born, Kudielka, Schlotz, & Wust, 2007) and anticipation of the demands to be faced in the day ahead (Fries et al., 2009). The two principal parameters of the CAR are total cortisol secretion over the awakening period and the increase in cortisol over the same period (Chida & Steptoe, 2009; Preussner, Kirschbaum, Meinlschmid, & Hellhammer, 2003). 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).

A number of cross-sectional investigations have found the CAR to be related to various work related factors including: work stress stress (Kunz-Ebrecht, 2004a), work strain (Alderling, Theorell, De La Torre, & Lundberg, 2006); time pressure, over commitment and effort-reward imbalance (Eller et al., 2006; Wust, Federenko, Hellhammer, & Kirschbaum, 2000). However, the CAR has been shown to demonstrate substantial within-person variability (Adam, Hawley, Kudielka, & Cacioppo, 2006; Dahlgren, Kecklund, Theorell, & Åskerstedt, 2009; Hruschka, Kohrt, & Worthman, 2005; Kirschbaum & Hellhammer, 1999; Stalder, Evans, Hucklebridge, & Clow, 2010; Stalder, Hucklebridge, Evans, & Clow, 2009; Stone et al., 2001), and the workplace is increasingly being recognized as representing a relatively dynamic environment, with the nature and magnitude of psychosocial demands in particular demonstrating temporal variation. This raises important methodological considerations for psychophysiological assessment of employees. Several authors have addressed this issue by incorporating a non-work day as a form of vanilla baseline with which to compare the work day CAR (Kunz-Ebrecht, Kirschbaum, Marmot, & Steptoe, 2004b; Liberzon, Abelson, King, & Liberzon, 2008; Maina, Palmas, Bovenzi, & Filon, 2009; Schlotz, Hellhammmer, Schultz, & Stone 2004; Thorn, Hucklebridge, Evans, & Clow, 2006) demonstrating a greater CAR on workdays when compared to non-work days. Although Schlotz et al. (2004) also found the CAR to demonstrate a high level of stability across six consecutive work days it is important to note that no assessment of daily psychosocial characteristics was undertaken (predicted or actual) and 36%

of the participants were either unemployed or retired. More recently, the magnitude of the CAR was shown to increase among a cohort of experienced sailors from day one to day three of a sea voyage, although this finding was based upon a limited sample (Liberzon et al., 2008). Nevertheless, the change in CAR according to the specific job-related characteristics on the day of assessment may potentially provide valuable information relating to the effect that work is having on individual employees. This highlights the importance of attending to the nature of the sampling day and provides evidence that chronic work-related factors are related to within-subject variation in the response.

The aim of the present study was therefore to investigate whether variation in the anticipated demand of work influences the cortisol awakening response. It was hypothesized that that the response would differ according to i) the relative anticipated demand (low versus high) and ii) the nature of the assessment day (work day versus weekend day).

Methods

Participants were recruited from staff at a UK University via an advertisement placed on the staff intranet. Inclusion criteria required participants to be free from illness and injury, not suffering any perceived work impairment and employed on a permanently contracted basis for a minimum of 25 hours per week in a role consisting primarily of mental demands (lecturers and academic support staff with teaching responsibilities). 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 hypothalamic-pituitary-adrenal function; diagnosed or self-reported diseases; perceived impaired work-related ability or functional capacity. The Work Ability Index (Tuomi, Ilmarinen, Jahkola, Katajarinne, & Tulkki, 2006) was used to screen participants for disease and perceived ability to perform their own work (only participants reporting a work ability index of 37 or above, equating to good or excellent categories, were included). Recruitment was deliberately restricted to a single institution in to eliminate the potential for inter-organizational differences to confound findings, e.g. different organizational 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. No incentives or compensation were provided for participation. Approval for the study was obtained by the Research Ethics Committee of the University's Faculty of Health, Life and Social Sciences. All data collection occurred between the months of August and December 2012.

Participants had their weight and height measured and completed both the International Physical Activity Questionnaire and the Work Ability Index (Tuomi et al., 2006) prior to undergoing a familiarization session to ensure they were comfortable with the protocol for saliva collection. Participants were advised that it was important that they attempt to provide the initial sample immediately upon waking with the second sample 30 minutes later, but that they should record accurate sampling times even if unable to comply with the protocol. Participants were instructed not to brush their teeth until they had completed 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. Before leaving the laboratory, participants were required to select two work days which they anticipated would contain differing levels of work-related demand on which to obtain samples. They were then provided with 6 pre-labelled Salivette collection tubes. Workday samples were taken to the laboratory on the morning of the day of collection and immediately frozen at -20°C. At this stage participants provided a measure of anticipated work-related demand using a visual analogue scale, a method which 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. Weekend samples were stored in the participant's home freezer and delivered to the laboratory on the next working day and stored in the freezer.

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 0.012-3.000µg/dl and a sensitivity of <0.007µg/dl. Absolute measures of salivary free cortisol were determined as the concentration of cortisol (nmol/l) present in saliva samples on awakening and 30 minutes post awakening.

A 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 paired-samples t-test was performed to test for differences in anticipatory demand between work days. The effects of sampling time and day were investigated by means of a repeated measures ANOVA with two within person factors: day (less demanding work day/more demanding work day/weekend) and time of day (awakening and 30 minutes post-awakening), controlling for the effects of gender. 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. Significance was set at $p<.05$ for all statistical analyses. Although all samples were included in the biological analysis, where participants failed to provide a complete set of saliva samples, those participant's results were excluded from statistical analysis to reduce the potential effect of inter-individual variation.

Findings

Five participants provided at least one non-adherent salivary cortisol sample; either as a result of failing to provide a full complement of samples, or providing at least one dry sample. This level of adherence is not unusual; previous studies have reported levels of non-compliance ranging from between 14 to 44% (Karlson, Eek, Hansen, Garde, & Ørbaek, 2010; Maina et al., 2009; Wüst, Wolf, Hellhammer, Federenko, Schommer, & Kirschbaum, 2000b) This resulted in the inclusion of a total of 45 samples, obtained from the remaining 15 participants (Table 1), in the statistical analysis.

Table 1. Participant characteristics

	Mean ± SD
Age (years)	38.20 ± 9.67
Gender (M/F)	(8/7)
Physical Activity (METS)*	4592.50 ± 5093.72
BMI (kg/m^2)	23.63 ± 4.06
Work Ability†	41.43 ± 5.34

* Weekly METS derived from the international physical activity questionnaire. † Work ability Index (7-27 = poor, 28-36 = moderate, 37-43 = good, 44-49 = excellent)

Awakening and sampling times are shown in Table 2. No differences were found in awakening time across the 3 study days $F(1, 38) = 2.70$, $p=.08$. 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.

Table 2. Mean self-reported salivary cortisol sampling times by day

Day	Sample 1	Sample 2
Low Demand	07:08 ± 34	07:49 ± 33
High Demand	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.

The two work days were found to differ significantly in terms of perceived acute demand (2.98 ± 0.78 v 4.69 ± 2.06, $p=.043$) (Fig. 1).

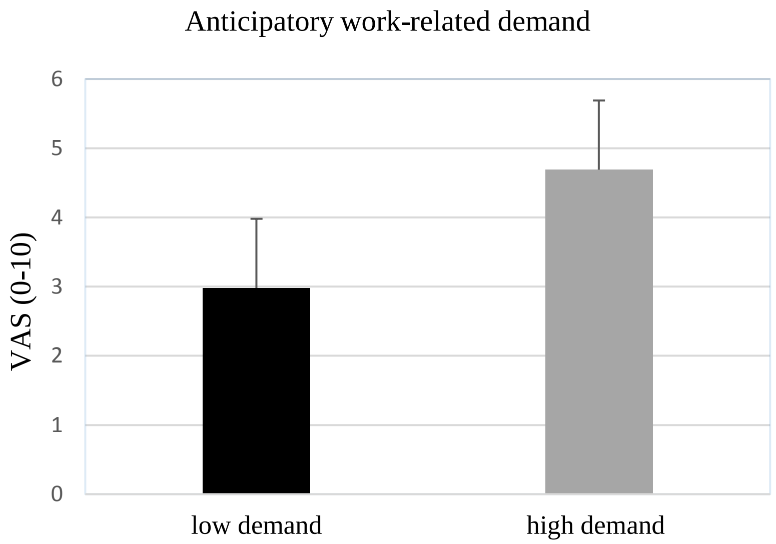

Figure 1. Anticipatory work-related demand measured using a visual analogue scale (n=15). * denotes significant difference

Results of the repeated measures ANOVA revealed there to be significant main effects of time $F(1, 13) = 23.54$, $p<.01$ confirming the presence of a distinct rise in salivary cortisol over the thirty minutes post awakening (Fig. 2).

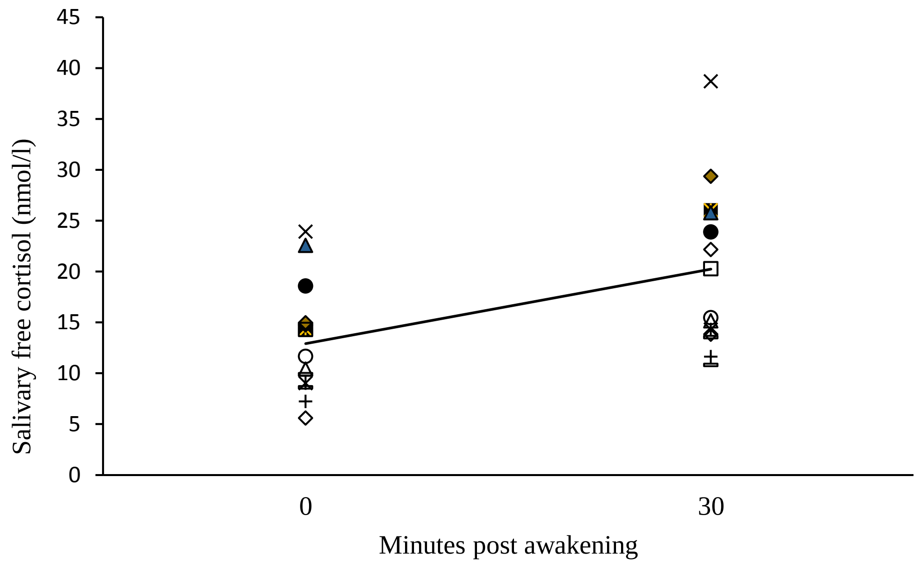

Figure 2. Mean salivary free cortisol by sample time

An awakening response was observed on all three study days with salivary free cortisol being greater 30 minutes post awakening than on awakening (Fig.3). The response was found to differ according to the type of day (F [2, 26] = 5.70, p<0.01). Post hoc analyses (Bonferroni test) 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).

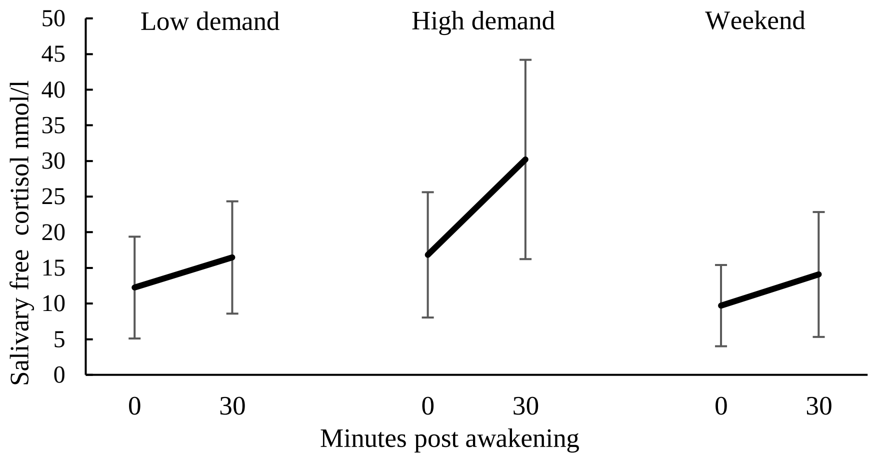

Figure 3. Mean awakening salivary cortisol by day

Discussion

The present study was performed to investigate whether the acute anticipatory demand of work influences the release of salivary cortisol over the awakening period and the results demonstrate the existence of a marked increase in salivary cortisol in the period immediately following awakening in this cohort of healthy adults. It was hypothesized that acute anticipatory work-related demand would affect the CAR and this was supported by the findings, as the response was greater on the high demand work day compared to the low demand work day. Secondly, it was hypothesized that the CAR would be greater on work versus non-work days and the results partially support this hypothesis: weekend CAR was lower than the "high demand" work day, but not the "low demand" work day. Given that the workplace has previously been shown to contain a high degree of day-to-day variation in demand (Totterdell, Wood, & Wall, 2006), workload (Ilies et al., 2007; Ilies, Dimotakis, & De Pater, 2010; Sonnentag, & Bayer, 2005) job satisfaction (Ilies, & Judge, 2002) and mood (Miner, Glomb, & Hulin, 2005) these results are, perhaps, not particularly surprising. However, although cardiovascular activity has been shown to be vary according to daily work characteristics (Campbell, Westbury, Davison, & Florida-James, 2016; Ilies et al., 2010; Kamark et al., 2005) very few investigations have given consideration to whether the cortisol awakening response demonstrates similar variation. Furthermore, although the CAR has previously been shown to vary among a group of novice sailors according to whether they were on or offshore (Liberzon et al., 2008) these two disparate physical and social environments might reasonably be expected to affect the anticipatory response to the demands to be faced in the day ahead. In contrast the present study investigated employees within a relatively stable working environment in an attempt to elucidate the effects of variation in the magnitude of anticipatory work-related demand. The results therefore suggest that day-to-day variations in the perceived acute demands of work are possibly associated with the functioning of the hypothalamic-pituitary-adrenal axis.

The limitations of relying purely upon cross-sectional investigations of the workplace were highlighted in a recent review of the literature (Uchino, Bowen, McKenzie, & Birmingham, 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 predicted 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. According to the management standards approach, academic staff in the UK report high levels of autonomy over their working practices (Campbell et al., 2016; Kinman & Court, 2010) and may therefore deliberately schedule peaks and troughs into their workload according to institutional demands and academic semesters, in order to allow for work recovery to occur. If these findings are considered in relation to the buffer hypothesis of the job demands-control model (Karasek, 1979), they may go some way to explaining the moderating effect of control upon wellbeing even in the face of high demand (see Van der Doef & Maes, 2007 for a review). This proposed relationship between high levels of autonomy and variation in workday CAR could have significant implications for work design. Both autonomy and task variety feature as dimensions of task characteristic within the Work Design Questionnaire (WDQ; Morgeson & Humphrey, 2006), which may be particularly important for individuals working within an academic role. Further investigation using an integrative approach aligning these specific dimensions of the WDQ with the CAR over multiple work days would be valuable.

Nevertheless, 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 were equivalent in the level of anticipated 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 might 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 non-work day.

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, Kirschbaum, & Steptoe 2004). However, some 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, Plessow, Kirschbaum, & Stalder, 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). 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.

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 generalizability 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 two 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 analyze the area under the curve. Additionally, no consideration was given to the day of the week upon which the working days occurred.

Conclusion: 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, while the CAR is an appropriate measure for investigating the effects of anticipatory work upon an individual, it is important to attend to the acute context of the assessment. Adopting an approach which considers the intra-individual variation in the response 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 an integrative model which combines subjective psychosocial questionnaires and ambulatory physiological measures into a coherent assessment of employee wellbeing.

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