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Sleep quality and the cortisol awakening response (CAR) among law enforcement officers: The moderating role of leisure time physical activity

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ABSTRACT

Objective: The goal of this study was to investigate the role of leisure time physical activity (LTPA) on the association between sleep quality and the cortisol awakening response (CAR) in people with an occupation that exposes them to high levels of stress.
Methods: Participants were 275 police officers (age = 42 years ± 8.3, 27% women) enrolled in the Buffalo Cardio-Metabolic Occupational Police Stress (BCOPS) study (conducted between 2004 and 2009). Officers provided four salivary cortisol samples (on awakening and 15, 30, and 45 min after awakening). Hours of leisure time physical activity were assessed using the Seven-Day Physical Activity Recall questionnaire. Sleep quality (good/poor) was evaluated using the Pittsburgh Sleep Quality Index (PSQI) scale. Analysis of covariance and repeated measures models were used to examine the association of sleep quality to the two aspects of CAR: cortisol levels (total area under the curve (AUC_G), mean, and peak cortisol) and cortisol profiles (the overall pattern in cortisol level during the 45 min period following awakening, the increase in cortisol from baseline to average of post awakening values (mean increase), and area under the curve with respect to increase (AUC_I)). Analyses were stratified by participant level of reported LTPA (*sufficiently vs. insufficiently active,* defined as ≥ 150 vs. < 150 min/week of moderate intensity activity, respectively). Since cortisol activity is known to be influenced by gender, we conducted additional analyses also stratified by gender.
Results: Overall, results demonstrated that LTPA significantly moderated the association of sleep quality with CAR. Among participants who were sufficiently active, CAR did not differ by sleep quality. However, in those who were insufficiently active during their leisure time, poor sleep quality was associated with a significantly reduced level of total awakening cortisol secretion (AUC_G (a.u.) = 777.4 ± 56 vs. 606.5 ± 45, p = 0.02; mean cortisol (nmol/l) = 16.7 ± 1.2 vs. 13.3 ± 0.9, p = 0.03; peak cortisol (nmol/l) = 24.0 ± 1.8 vs. 18.9 ± 1.5, p = 0.03 for good vs. poor sleep quality, respectively). The normal rise in cortisol after awakening was also significantly lower in inactive officers with poor sleep quality than in those with good sleep quality (mean increase (nmol/l) = 6.7 ± 1.5 vs. 2.3 ± 1.2, p = 0.03; AUC_I (a.u.) = 249.3 ± 55 vs. 83.3 ± 44, p = 0.02 for those with good vs. poor sleep quality, respectively). While findings for male officers were consistent with the overall results, CAR did not differ by sleep quality in female officers regardless of LTPA level.
Conclusion: Findings of this study suggest that poor sleep quality is associated with diminished awakening cortisol levels and dysregulated cortisol patterns over time, but only among officers who were inactive or insufficiently active during their leisure time. In contrast, sleep quality was not associated with any measures of CAR in officers who reported sufficient activity, suggesting a potential protective effect of LTPA. In analyses stratified by gender, findings for male officers were similar to those in the pooled sample, although we found no evidence for a modifying effect of LTPA in women. Future longitudinal studies in a larger population are needed to confirm these findings and further elucidate the relationships between LTPA, sleep quality, and cortisol response.

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1. Introduction

Poor sleep quality is a serious public health concern in the United States (Colten et al., 2006) and disproportionately affects chronically stressed populations, including those working in law enforcement and other stressful occupations. For example, in a controlled study of 1063 variable and stable shift workers, the prevalence of poor sleep quality was significantly higher among police officers than in those not involved in emergency services (64 vs. 45%, respectively) (Neylan et al., 2002). In a recent study of U.S. and Canadian police officers, 29% reported excessive sleepiness, 26% reported falling asleep while driving at least once in a month, 34% had obstructive sleep apnea, and 40% had at least one sleep disorder (Rajaratnam et al., 2011). Poor sleep quality has been linked to numerous chronic health conditions (Buxton and Marcelli, 2010) and to elevated risk for both fatal and non-fatal injuries (Vila and Kenney, 2002). Poor sleep quality is also thought to promote activation of the autonomic sympathoadrenal system and the hypothalamic-pituitary-adrenal (HPA) axis, the major neuroendocrine stress systems that enable us to deal with everyday challenges (Meerlo et al., 2008). Meerlo et al. contend that sleep deprivation may not only have a direct activating effect by itself but, in the long run, may also affect the reactivity of these systems to other stressors and challenges.

The stress hormone cortisol is the end product of the HPA axis and facilitates the organism's ability to adjust and adapt to internal and external demands (Fries et al., 2009). The change in cortisol levels follow a circadian rhythm (Clow et al., 2010; Fries et al., 2009) that involves three discrete components: (1) the first phase of cortisol circadian rhythm is the cortisol awakening response (CAR) which is defined as the sharp rise in cortisol levels that occurs immediately after awakening, followed by sharp decline during the next few hours, (2) a gradual decline in cortisol levels during the remainder of the day, reaching the lowest point during the first half of the sleep period (approximately midnight), and (3) an increase in cortisol levels during the second half of the sleep period until waking. A detailed discussion including graphical illustration of these three distinct phases of cortisol circadian rhythm is reported elsewhere (Elder et al., 2014; Debono et al., 2009; Selmaoui and Touitou, 2003; Weitzman et al., 1971). Typically, the CAR is characterized by a rapid increase in cortisol levels that peaks around 30 min post awakening (Clow et al., 2010, 2004; Wust et al., 2000; Fries et al., 2009). During the CAR period, cortisol levels typically increase by 38%–75% relative to the baseline cortisol value at awakening.

The CAR has been extensively used as biomarker of HPA axis sensitivity to stress. As a marker of HPA axis function, CAR is a considered a reliable measure of cumulative or 'allostatic' load on the body (Kudielka and Kirschbaum, 2005). For example, aberrant CAR has been linked to cardiovascular disease, susceptibility to infectious diseases, major depression (Kudielka and Kirschbaum, 2005), impaired telomere maintenance (Tromiyam et al., 2012), and psychological stress (Violanti et al., 2017; Duan et al., 2013; Steptoe et al., 2000; Pruessner et al., 1999). In addition, prospective studies have shown CAR to predict psychological health outcomes including peritraumatic dissociation, acute stress disorder, and major depression in police officers and other populations (Vrshek-Schallhorn et al., 2013; Inslicht et al., 2011). This particular measure of HPA axis activity has, therefore, garnered increasing interest as an overarching biomarker for health status and risk for morbidity and mortality. With the advent of convenient home sampling devices, cortisol can be reliably measured in saliva, providing a non-invasive index of HPA activity. Because of the relatively low cost and ease of collection of saliva samples in field settings, salivary CAR is especially relevant in epidemiologic studies of large populations where the use of invasive measures is too costly or impractical to implement. In this context, it is generally agreed that the CAR provides a reliable, non-invasive measure of this hypothalamic adrenocortical activity, especially because it also accurately reflects free cortisol levels (Wust et al., 2000; Pruessner et al., 1997). For these reasons, salivary cortisol measures have been a preferred method of risk assessment in many occupational health studies (Adam and Kumari, 2009; Koh and Koh, 2007; Violanti et al., 2006).

Despite considerable research on causes and correlates of HPA axis activation, there is limited information on the role of HPA axis activity in sleep and specifically, on CAR's relationship to sleep (Devine and Wolf, 2016; Elder et al., 2014). Systematic reviews of prior epidemiologic and experimental studies that examined the association of sleep measures with CAR reported inconsistent findings (Elder et al., 2014; Garde et al., 2011); both increases and decreases in CAR with poor sleep quality have been reported. One potential reason for variation in findings could be of the failure to consider modifiable lifestyle factors that could play a moderating role. Physical activity is known to improve cardiovascular fitness (Meyers et al., 2015), and recent reviews of both cross-sectional and longitudinal studies suggest that physical activity can have beneficial effects on a broad spectrum of physical and mental health outcomes (Brand et al., 2010; Flishner, 2005; Hamer, 2012; Penedo and Dahn, 2005). Regular leisure time physical activity also has a moderate, dose-dependent beneficial effect on sleep quality (Kredlow et al., 2015). However, to our knowledge, no studies have yet examined the potential modifying effects of leisure time physical activity on the association between sleep quality and CAR in any population, including those working in law enforcement and other high stress occupations. In this cross-sectional study of Buffalo police officers, we seek to address this gap; specifically, we investigate the potential differential associations of sleep quality with CAR in those who report high vs. low physical activity. Because gender and particularly sex steroids have been shown to influence cortisol response (McEwen, 2002; Pruessner et al., 1997; Wright and Steptoe, 2005), we also assess the potential modifying effects of gender on these associations.

2. Methods

2.1. Study population and design

Participants were officers enrolled in the Buffalo Cardio-Metabolic Occupational Police Stress (BCOPS) study. The BCOPS study was a cross-sectional study, with a prospective component, aimed at investigating the associations of occupational stressors with the psychological and physiological health of police officers. A total of 710 police officers who worked with the Buffalo, New York Police Department were invited to participate in the baseline study; 464 (65.4%) officers agreed to participate and were examined once during 2004–2009. No specific inclusion criteria were indicated for the study, only that participants be sworn police officers and willing to participate (Hartley et al., 2011; Violanti et al., 2006). A written informed consent was collected from each participant. The study was approved by the Internal Review Boards of the State University of New York at Buffalo, and the National Institute for Occupational Safety and Health (NIOSH).

2.2. Measures

Data regarding demographic, lifestyle, physical, biological, occupational, and psychosocial characteristics were collected from each BCOPS study participant using standardized instruments and protocols. Specific measures included in this study are detailed below. Leisure time physical activity (LTPA) level was assessed using the Seven-Day Physical Activity Recall questionnaire and the variable was utilized as a potential effect modifier. Demographic and life style characteristics were used as potential confounders for adjustment of the main association of interest between sleep quality and awakening cortisol response.

2.2.1. Major exposure variable: sleep quality

Sleep quality was assessed using the Pittsburgh Sleep Quality Index (PSQI), a well-established instrument validated in a wide range of