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Effects of sleep deprivation on serum cortisol level and mental health in servicemen

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ABSTRACT

This study aimed to investigate the effects of sleep deprivation on serum cortisol level and mental health and explore the correlations between them in servicemen. A total of 149 out of the 207 Chinese servicemen were randomly selected to go through 24 hour sleep deprivation, leaving the rest (58) as the control group, before and after which their blood samples were drawn for cortisol measurement. Following the procedure, all the participants were administered the Military Personnel Mental Disorder Prediction Scale, taking the military norm as baseline. The results revealed that the post-deprivation serum cortisol level was positively correlated with the factor score of mania in the sleep deprivation group ($r_{Sp} = 0.415$, $p < 0.001$). Sleep deprivation could significantly increase serum cortisol level and may affect mental health in servicemen. The increase of serum cortisol level is significantly related to mania disorder during sleep deprivation.

1. Introduction

As China has been going more and more industrialized, sleep loss has become increasingly serious in China. According to a survey about sleep in 2002, an estimated 45.4% people in China were suffering from sleeping problems and an estimated 28% of them had insomnia. Based upon the latest survey published by the Chinese Sleep Research Association in 2010, the estimated incidence of insomnia in China has reached as high as 38.2%. Hence, insufficient sleep duration has become a prevalent issue in our society, tending towards worse. Sleep is commonly viewed as a restorative process that influences homeostatic regulation of the autonomic, neuroendocrine, and immune system (Dinges et al., 1995; Krueger and Toth, 1994) and maintains normal physical functioning for all humans regardless of sex, age or ethnic origin (RECHTSCHAFFEN and BERGMANN, 2002). Since sleep plays an important role in learning, memory processing, cellular repair and brain development (Dinges, 2006; Graven, 2006; Stickgold and Walker, 2007; Tononi and Cirelli, 2006), sleep deprivation as a stressor could exert great influence upon cognitive function, motor performance and emotion (Chee and Chuah, 2007; Kahn-Greene et al., 2007), affecting the neuroendocrine stress systems and aggravating depression, anxiety and other mental disorders in the long term (Meerlo et al., 2008). Circadian rhythmicity and sleep play important roles in the regulation of plasma cortisol concentration by the hypothalamo-pituitary-adrenal (HPA) axis (Guyon et al., 2014). Experimental evidence indicates that sleep deprivation may affect cortisol levels and its circadian rhythm (Thorsley et al., 2012). Numerous studies have found links between sleep and changes in cortisol concentration, but the implications of these results have remained largely qualitative. A couple of studies showed that sleep deprivation or sleep loss had demonstrated to result in a significant elevation of cortisol levels (Lac and Chamoux, 2003; Omisade et al., 2010). This negative relationship has been advocated by several correlational studies (Balbo et al., 2010), as well as by experimental studies on total or partial sleep deprivation (Rodenbeck et al., 2002; Vgontzas et al., 2003). On the other hand, sleep deprivation is considered to be able to affect various affective disorders, depression in particular, positively (Voderholzer et al., 2004) or negatively (Rao et al., 2009). A study on chronically restricted sleep inducing depression-like changes in neurotransmitter receptor sensitivity and neuroendocrine stress reactivity in rats indicated that disrupted and/or restricted sleep might contribute to the symptomatology of mood disorders (Novati et al., 2008), though the possibility of other factors

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influence such as forced physical activity exists. Hypothalamo-pituitary-adrenal (HPA) axis hyperactivity, higher cortisol levels, a decrease in glucocorticoid receptors and lower negative feedback in bipolar disorder episodes were found during euthymia, depression and mania (Daban et al., 2005; Fries et al., 2009). The study of acutely hospitalized manic patients reports elevated plasma cortisol levels (Cookson, 1985). According to recent studies, sleep deprivation could affect neuroendocrinology and affective disorder at the same time, and neuroendocrine maladjustment maybe the reasons of affective disorder. We hypothesize that neuroendocrine maladjustment is closely linked with mental disorders during sleep deprivation.

Previously, some sleep deprivation studies were based upon animal subjects, the conclusion of which could hardly apply onto human body. Small sample size has also been one of the shortcomings among the few sleep deprivation studies based on human subjects. Particularly, studies on endocrine hormone changes effects induced by sleep deprivation on affective disorder with a sample size more than 30 are scarcely seen in general population groups, let alone special population groups, such as the military personnel. In military settings, where irregular sleep schedules are common due to operational constraints, a research about U.S. Army officers showed that soldiers slept only 3.0 h during the exercise and some of them were active throughout (Lieberman et al., 2005). To the best of our knowledge, up to now, there has been no commonly accepted conclusion concerning the mechanism by which sleep deprivation induces affective disorders, such as mania and depression. In our study, based upon our previous researches, we found out that serum renin, angiotensin II, and cortisol, serum dopamine, epinephrine and norepinephrine increase induced by sleep deprivation (Sun et al., 2013) and serum renin, cortisol were closely linked with mental resilience (Sun et al., 2014). Therefore, the aim of this study was to investigate effects of cortisol level change induced by sleep deprivation upon mental status and to determine the optimum cut-off value of serum cortisol as a biochemical indicator to predict mental status change in servicemen.

2. Methods

2.1. Participants

A total of 207 servicemen from a military unit whose title cannot be disclosed due to confidentiality consideration were randomly selected by cluster sampling based upon the following inclusion criteria: physically and mentally healthy, no history of mental illnesses; no recent sleep shortage, fatigue and trauma; not on any medication, nor any traumatic life events within one month before testing; no smoking or over-drinking alcohol or coffee or tea within 48 h before testing. In order to guarantee the representative power to the most extent, and derail routine military training schedule to the least extent, we selected 149 servicemen out of the total as a convenient sample by cluster random sampling, leaving the rest (58 participants) as the control group.

2.2. Procedure

Three trained research fellows (one clinical chief doctor, one attending doctor and one professional laboratory technician) were involved into the procedure. All 3 research fellows had been trained for the procedure beforehand for unified principles. The procedure was carried out in an exclusive sleep laboratory in the General Hospital of the People's Liberation Army (PLA) in Beijing. All participants were instructed to collectively stay in the laboratory and its controlled vicinity for 7 days of baseline preparation. During this preparation period, all the participants were served with standard meals three times a day without content of alcohol or tea or coffee or chocolate, and allowed to be active within a certain limit. No vigorous activity or smoking was allowed. Sleep diaries were kept by simple reviews for all participants every morning including information on sleep duration, sleep quality, awakening time and any abnormal events during sleep the night before. After 7 days of normal sleep preparation, the sleep deprivation procedure started at 8 a.m. on Day 8 and ended at 8 a.m. on Day 9, during which a total of 148 out of the 149 servicemen underwent 24 hour total sleep deprivation. The 1 participant who found the procedure insufferable was allowed to quit prematurely. During the 24 h, the laboratory conditions were standardized as follows: all participants were confined to a large lobby, reading, watching TV or movies (with lights on), playing poker or chess, or walking outside for a short span of time under close surveillance. No running or rigorous activities were allowed. All laboratory conditions were kept the same as the preparation period. Three research fellows had been monitoring by paying close attention to each and every one of them, preventing dozing off or naps. When a subject appeared drowsy, a staff member would engage him in conversation. All subjects in sleep deprivation group had blood drawn for cortisol level measurement at 8 a.m. on Day 8 as the baseline and 8 a.m. on Day 9 after-deprivation measurements respectively for comparison. The moment when the 24 h ended, all subjects in sleep deprivation group and control group were instructed by research staff to run group test with Military Personnel Mental Disorder Prediction Scale for mental health measurements. The protocol for this study was approved by the Human Research Ethics Committee in No. 102 Hospital of PLA. Informed consents were obtained from all participants.

2.3. Measurements

SCL-90 and EPQ are usually used to assess mental status for civilian purpose, but inappropriate for military purpose, taking into consideration extraordinary military environment and exceptional nature of military tasks. The Chinese version of Military Personnel Mental Disorder Prediction Scale (Tu et al., 2009) was used to assess mental status of the sleep deprivation group. Military Personnel Mental Disorder Prediction Scale was developed by the PLA Prevention and Treatment Centre of Psychological Diseases, consisting of 96 items in 12 factors, namely family and past history, growing experience, introversion personality, stressor, lack of psychological defense, lack of social support, psychosis, depression, mania, neurosis, personality disorder and a lying factor. It is dichotomously scored with "*yes*" scoring "0" and "*no*" scoring "1". Higher score indicates worse mental status and higher mental disorder risks. Repeated verifications indicated that Cronbach's alpha coefficient of the general scale was 0.868, and those of the factors ranged from 0.359 to 0.789 ($p < 0.01$); correlation coefficient of all factors ranged from 0.140 to 0.842 ($p < 0.01$). All these have demonstrated that this scale has very good reliability and validity, meeting strict psychometric standards. In addition, the military norm of mental health established with a large sample of 8002 servicemen was used as the baseline level in this study (Zhang, 2011). On the other hand, radioimmunoassay (RIA) was employed by the Endocrine Laboratory of General Hospital of Chinese PLA to measure cortisol level using commercial kits (instrument specifications: XH6080; agent company: DIAsouce Immunoassays s.s. Belgium,) with intra- and interassay coefficients of variations of less than 10%. All measurements were run in parallel.

2.4. Quality control

Questionnaire exclusion criteria were as follows: those with lying factor score higher than mean plus 1.96 times of standard deviation (95% confidence interval), and those were arbitrarily filled and incomplete. No ID registration was required in order to dispel misgivings. A total of 206 (the 1 quitter excluded) questionnaires were recollected. Eight pieces in sleep deprivation group were excluded, leaving 140 pieces and making effective rate 94.59%, and 5 pieces in control group were excluded, leaving 53 pieces and making effective rate 91.38%. All the blood samples of the subjects whose questionnaire were excluded were included into the final results for data analysis. The sample sizes of different groups at different stages of this study are shown in Table 1.