Circadian Levels of Serum Melatonin and Cortisol in relation to Changes in Mood, Sleep, and Neurocognitive Performance, Spanning a Year of Residence in Antarctica

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Abstract

We assessed the circadian rhythm of 20 subjects who wintered over at Maitri (70'S, Il'E), India's permanent Antarctic station, from November 2010to December 2011. Serum cortisol and melatonin levels were measured by radioimmunoassay at 8 am, 3 pm, 8 prn, and 2 am in a Single day, once each during the polar summer and winter photoperiods. Conventional psychological tests, Depression, Anxiety, and Stress Scale (DASS-42), Epworth Sleepiness Scale (ESS), and a computerized neurocognitive test battery were used to measure mood, sleep, and cognitive performance. *Results.* The mean scores for DASS42 were higher during midwinter suggesting the presence of "overwintering:' Mean diurnal cortisol levels during summer and winter were comparable, but the levels of melatonin were markedly higher during winter. Higher 8 am melatonin levels were associated with better sleep quality, lower depression scores, and better performance in tasks like attention, visual memory, and arithmetic.

Introduction

Residence in Antarctica exposes humans working in the research bases to extremes of weather and photoperiod, in addition to geographic and social isolation. The annual average solar radiation decreases with Increasing latitude, and this difference is marked during winter than in mid- summer in the circumpolar regions. This alters temporal homeostasis and affects sleep wake cycles, mood, cognition and work performance of base personnel. The psychological disturbances in Antarctica, referred to as the "over winter syndrome;' may also relate to change in the circadian rhythms of the hormones cortisol and melatonin (Yoneyama et al., 1999, Midwinter and Ardent 1991, Ross et al., 1995. [1-3]. Photic stimuli are the primary synchronizer of the endogenous circadian pacemaker in the suprachiasmatic nucleus of the anterior hypothalamus. The endocrine control over the circadian pacemaker is reflected by the changes in serum levels of cortisol and the pineal indoleamine melatonin. Melatonin, noradrenaline, and acetylcholine decrease with light activation, whereas cortisol, serotonin, GABA, and dopamine levels increase. In normal subjects, we expect a peak melatonin level at approximately 3 am, whereas cortisol peaks at approximately 9 am (Roberts 2000) In healthy individuals, the transition from low light to bright light in the morning results in a surge in cortisol levels and a decline in melatonin levels (Leproult et al., 2001) Since the photoperiod is the principal factor regulating seasonal adaptation, melatonin responses may mediate changes in endocrine, cognitive, psychological, and immune function (Cutolo et al., 2005) There is mounting evidence to suggest that long-term disruption of circadian rhythm correlates with disease states such as ischemic stroke (Brown et al 2009) heart disease (Portaluppi et al., 2007) metabolic dysfunction, and glucose intolerance (Scheer et al., 2009) Additional studies have also found that chronic shift work is significantly associated with an increased risk of colorectal, endometrial, and prostate cancers (Reiter 2007)Disintegration of sleep wake cycles and poor sleep health is also associated with a range of neuronal diseases such as Alzheimer's or Huntington's disease Hu et al., 2009, Morton et al., 2005) Psychological research in Antarctica provides insight into how individuals (and groups) function in an extreme and isolated milieu

Sleep disturbances and psychological changes have been reported in overwintering teams, but only one study on 9 individuals has tested the effect of the changed diurnal rhythm in the Antarctic on human cognition and performance (Corbett et al., 2012). Previous studies have reported that circadian cortisol levels have an important role in cognition in an age independent manner. Studies demonstrated that frequent trans meridian flyers with a disrupted diurnal cycle had higher evening cortisol levels, which was associated with cognitive deficits and right temporal lobe atrophy (Cho 2001). Objective assessment of cognitive performance is important for comparison and reproducibility. Computerized neurocognitive tests (CNT) allow accurate measurements of reaction times and test-retest reliability. However, they may be less reliable than conventional tests when traits like verbal skills and personality are being tested (Gualtieri and Johnson 2006) Hence a combined approach is suitable in situations where comprehensive evaluation of personality and serial testing of cognitive skills is needed.

The objective of this study was to (i) evaluate the seasonal variation in serum cortisol and melatonin diurnal rhythms during the polar summer and winter photoperiods, (ii) study mood and depression, and (iii) assess the change in objective neurocognitive performance of the base personnel over a period of one year in Antarctica.

2. Materials and Methods

2.1. Subjects and Study Design. Twenty male members of the 30th Indian Scientific Expedition to Antarctica (ISEA), certified to be in GDod mental and physical health and free of intrinsic sleep disorders following medical and psychiatric examination and acclimatization training, were recruited for this prospective study with written informed consent. The study was approved by an Institutional Ethics Board of the National Centre for Antarctic and Ocean Research (NCAOR), India's nodal agency for Antarctic research and was conducted in accordance with the standards of the Declaration of Helsinki. The study was started in November 2010 soon after arrival of team members in Antarctica and the group was followed up prospectively till the conclusion of the expedition in December 2011.

2.2. Study Protocol. The Indian Antarctic research base Maitri is located at 70"45' 57" S, 11"44' 09" E. The over- wintering team consisted of 6 scientists and 14 technical support staff who are required to keep the base functional and the scientific experiments running. All the personnel are required to maintain the same sleep rhythm (wake at 0700 hours UTC) and work schedule except for one person who is on night watch, which is a periodic duty once every ten days by rotation. One meteorologist also maintained a night shift duty for the greater part of the year.

The winter period at 70"S starts in mid April and lasts till October. Serum levels of melatonin and cortisol were measured in the subjects at 8 am, 3 pm, 8 pm, and 2 am in a Single day using an indwelling antecubital catheter during 2 different photoperiods: once during summer and the other during the polar winter. The samples reflecting the summer photoperiod were collected in January 2011, a few weeks after arrival in Antarctica, and processed to obtain serum which was stored at minus 25" Celsius until assay was done. Repeat serum samples were collected in June 2011 during the polar winter. The serum was frozen immediately and stored at minus 25"C. The samples were transported back to India on dry ice using monitored cold chain transport at -25"C to -70"C. Melatonin was measured by radioimmunoassay (RIA), using 1^{125} -rnelatonin (Labor Diagnostika Nord GmbH & Co. KG, Nordhorn, Germany). The reference range, as stated by the manufacturer, was 30-150 pg/mL. The sensitivity of the method was 2.3 pg/mL and the intra-assay variability less than 9.8 and inter-assay variability 8. The anti-melatonin antibody used had a cross reactivity of >0.1 with melatonin related metabolites or precursors. Serum levels of cortisol were assayed by GammaCoat RIA (DiaSorin, Stillwater, MN) with a sensitivity of 0.2 rtg/dL and intra-assay coefficient of variation (CV) of 6.5 and inter-assay variability of 9. The reference range was 7-25 rtg/dL for morning values and 2-9 rtg/dL for evening values.

2.3. Sleep Quality Evaluation. All subjects were required to maintain a sleep log over a 2-month period in summer and again in winter. The sleep log documented the sleep/wake times, caffeine and alcohol intake, nighttime awakenings, use of sleep aids such as sleeping pills, music, reading, total duration of sleep, and a subjective evaluation of restorative sleep. Epworth Sleepiness Scale (ESS) [16] and Morningness Eveningness Questionnaire (MEQ) [17] were administered on arrival, during summer and during winter. The ESS is a validated scale for measuring daytime sleepiness and the MEQ scores reveal individual adjustment to morning and evening photoperiods and the synchronization of the internal clock to work schedules.

2.4. Neurocognitive Evaluation. A combination of conventional psychological tests and a computerized neurocognitive test battery (CNT) were used to serially measure relatively mild degrees of neurocognitive impairment in the base personnel. CNTs were performed using Psychology Experiment Building Language (PEBL) Version 0.11. The tests included visual and verbal memory, attention, visual motor speed, arithmetic and reaction times, a modification of the Halstead Reitan Battery, to test domains likely to be relevant to wintering and working in a challenging environment like Antarctica (see Table 1). Neurocognition Tests: the battery of tests employed in this study included both conventional and computerized tests (Gualtieri & Johnson, 2006).

TABLE 1: Neurocognitive domains and tests used in the study protocol.

S.N.	Domain	Neurocognitive Test	References
1	Attention/concentration	Shifting attention test Digit span forward Continuous performance test	Tulsky et al. [18]
2	Executive function	Stroop test	Tornatore et al. [24]
3	Visual motor ability	Index finger tapping test (FTT)	Gill et al. [19]
4	Visual memory	Modified Rey Visual Design Learning test	Shapiro and Harrison [20]
5	Arithmetic	Speed and accuracy of simple addition, subtraction, multiplication and division equations	-
6	Speed of processing	Simple and choice reaction time	Lemay et al. [21]

5. Conclusions

Circadian rhythms are modulated by central pacemakers like melatonin and cortisol which synchronize to stimuli such as photoperiod and activity, and thus indirectly the internal clock becomes predictive of solar time. Our study found that the diurnal rhythm for cortisol was comparable during the polar summer and winter. In contrast, circadian secretion of melatonin was affected during the polar winter and higher levels persisted throughout the day, peaking physiologically at 2 am in both seasons. This was associated with better subjective sleep quality during winter. Again, higher levels of 8 am melatonin correlated significantly with better neurocognitive performances in tests for attention and immediate memory. We also report the effect of over wintering in our subjects reflected as higher depression, anxiety, and stress scale scores during the polar winter. This impaired cognitive performance in few subjects. Timing of artificial light exposure and usage of melatonin supplements in improving sleep and cognitive performance in expedition teams are of future research interest.

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