Spring snow lowers human melatonin

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ABSTRACT
Objectives. We set out to find out in which way seasonal changes of environmental luminosity could affect melatonin secretion in humans. Study design. For an entire year we collected every two months nocturnal urine samples from 20 male outdoor workers who lived and worked in an area of the circumpolar region from which exact data of solar irradiance and temperature were available. Methods. Melatonin secretion rates were assessed with our melatonin-specific radioimmunoassay. Results. Melatonin secretion was twice as high in December as in April, 0.88 ± 16 nmol/12 h (mean ± SE) vs. 0.43 ± 9 nmol/12 h, p < 0.05. Regression analyses showed that melatonin values best correlated inversely with solar irradiance reflected off the ground (the so-called 'albedo'). A tenfold increase in albedo for 1-4 weeks before the urine samplings were collected was associated with a ca. 50% reduction in melatonin secretion. The association with global irradiance was weaker and none existed with temperature or other environmental variables. Discussion. Light reaching the eyes via the snow or other reflecting surfaces appears to be most effective. These results help us to understand some of the mechanisms involved in certain biological phenomena that exhibit seasonal variations such as reproductive and self-destructive behaviours.

Key words: urinary melatonin, seasonal, annual, biorhythm, solar irradiance, visual perception

INTRODUCTION
Earlier studies from high-latitude countries have demonstrated that at some time points during the night or day, circulating or salivary melatonin reaches levels that are higher in winter than in summer (1,2), but subjects living under extreme Antarctic conditions did not exhibit any such seasonal changes in plasma melatonin (3,4). In the present study we sought answers to two questions. Firstly, are there significant seasonal changes in the secretion of melatonin in subjects whose exposure to solar irradiance with regard to duration and intensity is known? Secondly, is there a way to relate solar irradiance to melatonin secretion?

METHODS
Twenty healthy Caucasian males, aged 20-40 yrs, from the counties of Sodankylä, Kolari and Äkäslompolo (67-68 °N, 24-26 °E) gave their informed consent for this study. They were outdoor workers and their daily stays out of doors were recorded during a week before urinary samplings took place. They visited a nurse’s office every two months between 9 and 10 am, starting on 12 - 15 June and ending on 24 - 26 April the next year. On these visits they left their first voided urine samples. They were asked to empty their bladders 12 h before the urine collection in the morning. After the volumes of the urine samples were noted, the latter samples were stored at -20 °C before the assays got under way. Urine samples were measured by our now well-established 2-125I-melatonin radioimmunoassay method (5).
Daily sums of global and reflected (albedo) solar irradiance as well as daily mean temperature (four readings per day) were obtained from the Sodankylä observatory (67°20’ N, 26°20’ E). The solar irradiance was measured by a Kipp & Zonen pyranometer CM 11 with a 2 π viewing angle upwards (global irradiance) and a 2 π viewing angle downwards (reflected irradiance, albedo). The spectral range and the sensitivity of the pyranometer were 305 - 2800 nm and 0.004 - 0.006 V/Wm², respectively.

Melatonin secretion rates were obtained by multiplying urinary melatonin concentrations (nmol/ml) by urinary excretion rates (ml/12h). Melatonin secretion rates (nmol/12 h) in each subject were proportioned to their annual means and analysed by one-way ANOVA with repeated measures and Newman Keuls test for differences between the bimonthly means (BMDP, Los Angeles, CA, USA). The relationships between melatonin secretion rates and climatic data (temperature, global irradiance, albedo) were assessed by using multiple regression analyses. Since it was assumed that the climatic conditions that prevailed at the time of the urinary sample collections affected melatonin secretion rates, temperature and irradiance variables were integrated over the periods covering 1, 2, 3, 4 or 8 weeks before the day of urinary samplings. Solar irradiance values were transformed to logarithms, since the retinal cells discriminate luminosity more accurately on a logarithmic than on an absolute scale.

RESULTS
In this northern circumpolar area between oceanic and continental climates, the changes in temperature and global solar irradiance were large with maxima during June-August. The reflected solar irradiance, the albedo, was greatest in April and decreased soon thereafter as the snow melted. Small increases occurred in June-August (albedo from foliage) and in late September (first snow that melted away again). Melatonin secretion rate was highest, i.e. 0.88 ± 0.16 nmol/12 h (mean ± SE), in December and decreased steeply thereafter, reaching 0.43 ± 0.9 nmol/12 h in April (p = 0.03). During the other months (June, August, October and February) the secretion rates were between 50 and 77 nmol/12 h.

We then applied several regression models containing melatonin secretion rate as the dependent and solar irradiance (global or albedo) or temperature as explanatory variables, each alone or in combinations of two or three. For these purposes the explanatory variables were integrated backwards for 1, 2, 3, 4, or 8 weeks from the time when the urinary samples were taken. First we found that combinations of two or three explanatory variables did not improve the model. Significant regression coefficients (p<0.05) were found between melatonin and albedo up to four weeks, but none with global irradiance or temperature. In the correlation analyses melatonin correlated inversely (i) with global irradiance of the preceding 1 - 4 weeks through R values between - 0.22 and - 0.23 (p< 0.01), (ii) with albedo through R values between - 0.28 and - 0.34 (p< 0.001) and (iii) with temperature or with any of the values integrated for 8 weeks in a non-significant manner. Our results indicate that a tenfold increase in albedo over a period of 1-4 weeks prior to the urine samplings is associated with a ca. 50% reduction in melatonin secretion.

DISCUSSION
We have shown through measurements of the first voided urine samples in the morning that subjects living in northern circumpolar areas exhibit a significant seasonal melatonin rhythm. The melatonin secretion rate in December was twice as high as in April. This finding is in agreement with previous reports from latitudes 60 - 70 °N, in which serum or salivary melatonin levels of day- and night-time samples were higher in winter than in summer (1,2). Compared with summer values, daytime plasma melatonin or maximal plasma melatonin levels were elevated by 30-50% in winter. However, in studies from
Antarctica (74-77 °S) no significant seasonal changes in the amplitude or area under the curve of plasma melatonin were observed (3,4). It is, therefore, feasible that the bunker conditions and short outdoor stays in Antarctica, due to extremely low temperature, prevented any entrainment of melatonin secretion to the natural Zeitgeber, i.e., light. The free-running nature of the melatonin rhythm speaks rather for the absence of any Zeitgeber.

The knowledge of exact daily solar irradiance values gave us a possibility to analyse the relationships between temperature, global irradiance and albedo and melatonin secretion more accurately than had previously been possible. Significant regression coefficients were found between albedo and melatonin secretion rate, but none with temperature or global irradiance. There was a highly significant negative correlation between albedo and melatonin secretion rate (R = - 0.34), when the time factor was 4 weeks. This indicates that approximately 12 % of the variance in melatonin secretion was explainable by the albedo that prevailed up to 4 weeks prior to the taking of the urinary samples. Global irradiance explained only approximately 5 % of the variance. Thus, since the viewing angle of the eyes in humans is mostly directed downwards, radiation reaching the eyes via snow or other reflecting surfaces on the ground appears to be most effective. Similar conclusions have also been drawn earlier about the possibly harmful effects of UV radiation on the eyes (6). In lower latitude countries the effect of the albedo has to be smaller, but it may still be present e.g., on beaches, lakes, seas, and mountains.

Low melatonin levels in the spring may appear to be associated with disturbances in circadian rhythmicity, sleep disorders and increases in self-destructive behaviour: in northern hemisphere countries, for example, suicides peak in the spring, which is well documented (7,8). The impact of meteorological and biochemical factors on suicide rates has been widely studied, and elevated ambient temperature during the weeks preceding a suicide as well as low tryptophan availability at that time appear to be the best predictors; sunlight duration or daytime melatonin showed weaker associations (9-12). However, neither duration of sunshine nor cloudiness may be reliable indicators of the true amount of the light reaching the eyes, for light reflected off the ground remains underrepresented. Likewise, single daytime measurements (13), common in comparative melatonin studies, represent melatonin secretion poorly.

In summary, we have demonstrated that melatonin secretion rates in humans from a high-latitude country are twice as high in the winter as in the summer, and that the increase in the reflected solar irradiance, the so-called albedo, best explains the decrease in melatonin secretion. Our results also show that suppressed melatonin secretion as a predictor of reproductive competence or suicides has to be assessed through methods that detect melatonin secretion rates as well as the true admittance of solar irradiation to the eyes.

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