ABSTRACT

Objectives. To test the hypothesis that the unexpectedly low prevalence of winter depression in Iceland is explained by Icelanders enjoying more daylight, during the winter months, than allocated to them by latitude.

Methods. A conventional photometer was applied to measure illuminance on a horizontal surface at 64°8.8’ N and 21°55.8’ W every minute throughout the year. The illuminance thus measured was compared with computed illuminance, based on theoretical upper bounds.

Results. Daylight availability proved to be, on average, 60% of the theoretical upper bounds derived using clear sky conditions. Snow cover did not, on average, cause a significant increase in daylight availability. Great variability was observed in illuminance from day to day, as well as within days.

Conclusions. Average daylight availability does not explain the lower than expected prevalence of winter depression in Iceland. The great variability in illuminance might, however, affect the expression of winter depression, as could daylight quality and genetic factors. (Int J Circumpolar Health 2004;63(3):267-276)

Key words: daylight, daylight availability, illuminance, seasonal affective disorder, Iceland
INTRODUCTION

The latitude hypothesis (1) predicts a higher prevalence of winter depression in Iceland than measured by SPAQ (2-4). Measured by HADS (Hospital Anxiety and Depression Scale), the prevalence of anxiety and depression did not vary between seasons in Iceland according to a recent study (5). This suggests the contribution of factors, other than daylight, to the manifestation of mood disorders in Icelanders. A valid objection to this inference would be if Icelanders, because of reflection from snow (6), enjoyed substantially more daylight than predicted by latitude alone.

The main objective of this study is to assess whether, or not, due to climatic conditions, daylight availability in Iceland is greater than expected on the basis of latitude.

METHOD

Study design
A one-year study of daylight availability in Reykjavik was undertaken.

Environmental Data
A conventional photometer was applied to measure illuminance on a horizontal surface at 64°8.8’ N and 21°55.8’ W every minute throughout the year. The Engineering Research Institute of the University of Iceland undertook the data monitoring and data processing. The illuminance data are displayed in Figure 1, showing illuminance as a function of time. Data for two days are represented, the 6th and 7th of June 1998. The data from the 7th represent clear-sky conditions, while the data from the 6th show rapid fluctuations in illuminance during the period 3:00 to 13:00 hr, while the curve coincides with the curve from the 7th for the remaining part of the day. These rapid fluctuations are due to clouds causing almost instantaneous reduction and increase of illuminance, even above the theoretical clear-sky value, due to reflected radiant power. The illuminance over two months is illustrated on the multiplot depicted in Figure 2, showing the typical variability characterising Icelandic weather.
The Icelandic Meteorological Office provided quantification of snow cover for specific days, which was compared with the illuminance values of those days.

**Procedure**

To quantify daylight availability, the measured illuminance was compared with computed illuminance, based on theoretical models. Available engineering models can be used to predict illuminance due to clear-sky conditions without disturbances from meteorological processes and pollution. Such models use time and geographical location as input (see, for instance, 7). Comparison of recorded illuminance under clear-sky conditions with computed illuminance generated using an engineering model representing the direct sunlight illuminance and diffuse skylight illuminance (7, p. 363), reveals good correspondence. This is indicated in Figure 3. Hence, it is feasible to use this model to assess the upper bounds of daylight availability. In the follo-
Figure 2. Measured illuminance. (a) January 1998. (b) May 1998. Data for the 8th are missing.
wing, daylight availability is expressed in terms of illuminance availability, defined as integrated illuminance in klx-hr. The measured daylight availability is then finally expressed as a fraction of theoretical upper bounds.

RESULTS

Variability in illuminance has been investigated following the methodology outlined in the preceding section. Seasonal variations in illuminance have been assessed, on the one hand, using engineering models and, on the other, by applying the recorded illuminance data.
The results for 1998 are outlined graphically in Figure 4, using monthly averages of illuminance availability expressed in klx-hr. A clear seasonal variation is visualised, displaying monthly average daylight availability in December that is only about 2.5% of the corresponding value in June. Furthermore, it is seen that observed daylight availability (the light grey bars) is, in all cases, less than the computed values (the dark grey bars) derived using the above-mentioned engineering model and clear-sky conditions. These computed values are judged to be close to the upper bounds of daylight availability. The physical environmental effects that may possibly lead to still higher values are related to partially clouded sky, which can in-
crease reflected radiant power, and snow cover. Investigation of the contribution from clouds reveals, on average, a reduction of daylight availability in all cases. This seems to be due to the effects of clouds that cover the sun, yielding a greater reduction of the illuminance than the increase due to reflection from clouds. A detailed investigation on the effects of snow cover did not reveal any significant increase in daylight availability on average. This can also be seen by investigating the fraction of computed illuminance availability under clear-sky conditions shown in Figure 3. It is noted that there is not a statistically significant difference observed for different months, or different seasons, in the fraction of daylight availability. For the pre-
sent data, this fraction is in the range of 41 (December) to 72 (April) percent, with an average value of almost 60 percent. This corresponds reasonably well with the fact that, in Iceland, the cloud cover is close to 5/8 on average (when the cloud cover is measured in ‘eighths’). This can be seen in Figure 4. These results do not diminish the importance of reflected sunlight (albedo) from the snow cover as a contributing factor in melatonin secretion suppression observed in the circumpolar region (8).

The variability of the observed illuminance is very great, not only due to seasonal variations (see Figure 4), but also from day to day and during any given day, with rapid changes in weather conditions. This is illustrated in Figure 5. The hours of the day are given on the horizontal axis, while the day of the year is given on the vertical axis. The grey scale yields the hourly average illuminance in klx. The values are in the range of 0-90 klx. The figure shows clearly that, during summer, we may get days when the illuminance is comparable with good winter days. This great variability is due to the location of Iceland in the middle of the North Atlantic, in the dynamic passage of low pressure systems that shape and form the weather. It is suggested that this variability in daylight might be a factor contributing to the low prevalence of winter SAD (seasonal affective disorder) in Iceland.

DISCUSSION

The present study reveals large seasonal differences in the average daylight availability that would be expected taking the latitude of Iceland into consideration. Previous studies demonstrate that the prevalence of winter SAD in Iceland is, however, lower than predicted by the latitude hypothesis (see 4, for further discussion). The daylight availability in Iceland was therefore investigated and an attempt made to find whether, or not, it had an association with the unexpectedly low observed prevalence rate of SAD.

The main finding of this study is that the average daylight availability in Iceland during winter months is far from being greater than expected taking latitude into consideration. In fact, it is actually only 60%, or less, of the theoretical values determined for
clear sky conditions. This finding does not support a quantity-based hypothesis of reduced daylight being the sole cause, sufficient and necessary, of winter depression. It supports, albeit indirectly, the view that the aetiology of winter SAD is more complex than previously believed, possibly including genetic, socio-cultural and psycho-social factors. This does not, however, exclude the possibility that some still unknown qualities of Icelandic daylight during the winter months might contribute to explaining the prevalence of winter SAD in Iceland, which, considering the latitude, is surprisingly low. We look into that possibility in a recent paper (9) on the spectral composition of daylight in Iceland. Furthermore, we observed a great variability in illuminance from day to day, as well as within days. This is explained by the location of Iceland in the dynamic passage of low-pressure systems. The consequent variability in daylight might possibly contribute to explaining the low prevalence of winter SAD in Iceland.

We conclude that, contrary to what is generally believed, the quantity of available daylight may not be the decisive factor in the expression of winter depression. Its variability, however, may play a causal role in that process in Iceland.

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