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Average sunrise time predicts depression prevalence

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Abstract

Objective: Folk wisdom has it that early rising is associated with being "healthy, wealthy and wise." A physiologic explanation may be Wiegand's "Depressiogenic Theory of Sleep," which posits that excessive REM sleep causes depression. Sleeping late increases REM sleep, and thus may increase depression risk. Published depression prevalence research does not use arising time, but average sunrise time (AST) for cities might serve as an analogue for arising time. Two studies of depression prevalence in urban populations, the EURODEP Programme, which measured geriatric depression in nine European cities, and the Epidemiologic Catchment Area (ECA) study of five US centres, have so far lacked satisfactory explanations for the striking differences in depression prevalence between cities. It was hypothesized that differences in rising times between cities, as determined by AST, could explain the variability in depression prevalences. **Methods:** Correlations were calculated for published depression prevalences from the EURODEP and ECA studies, and AST for each site. **Results:** For both studies, depression prevalences are significantly correlated with AST, with later sunrise (corresponding to earlier arising times in relation to sunrise) associated with lower depression prevalence. **Conclusions:** The hypothesis that later rising from sleep is associated with increased depression was supported. The findings also suggest that a city's depression prevalence could be reduced by simple public health measures to manipulate AST, such as going to Daylight Saving Time (DST) year-round or shifting time-zone boundaries. For individuals, getting up earlier from sleep may be helpful in depression.

Keywords: Chronobiology; Circadian rhythm; Depression; Depressive disorder; Light; Prevalence; Prevention; Sleep; REM

Introduction

The well-known adage "Early to bed and early to rise, makes a man healthy, wealthy and wise" restates folk wisdom widely known in Europe since at least the 15th century [1]: getting up early contributes to physical well-being and productivity. In spite of its universality, it appears to have received little scientific scrutiny. Globus in 1969 [2] identified a syndrome of being worn-out, tired, lethargic and irritable, with fuzzy thinking and difficulty in getting going, in students who slept for 10 or more hours when not making up for a sleep deficit. A series of studies by Taub showed that extended sleep impairs performance on vigilance tasks [3], on auditory memory and vigilance and on visual reaction tests [4] and impairs alertness [5]. A recent study of the effects of a number of health-related behaviours on academic performance of students at Brigham Young University in Utah [6] found that wakeup times had the strongest association with Grade Point Average scores, with each additional hour of morning sleep contributing to a decrease of 0.13 points on the 0–4 GPA scale.

With respect to health, sleeping more than 9 h or less than 6 h increased the risk of dying by 1.6 times or more compared to sleeping 8 h per night [7]. A large study involving over one million participants found that mortality hazard was lowest for adults who slept between 6.5 and 7.5 h nightly [8].

Is there a physiologic basis for these findings? Michael Wiegand et al.'s [9] "Depressiogenic Theory of Sleep" posits that excessive REM sleep can cause depression. In normals, the first REM period typically begins about 90 min after sleep onset and succeeding REM periods recur with a frequency of 1 about every 90 min. The length of each REM period increases through the night [10], with the peak of REM propensity occurring in the morning, shortly after the nadir of the endogenous temperature

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rhythm [11] (8:30 a.m. in one study [12]). Thus, the timing of sleep may have a greater influence on the amount of REM sleep obtained than sleep duration, with individuals who sleep late, i.e., close to the REM peak, obtaining more REM sleep than those who get up early [13]. Wiegand's theory could therefore be extended as follows: late sleepers, to the extent that they exceed their REM sleep requirements, will be at greater risk for depression, or for depressive symptoms such as fatigue, than early risers. Additionally, it should be possible to treat depressions resulting from late rising by having the patient get up earlier, as suggested by studies on advancing the sleep–wake cycle [14,15]. It has been difficult to demonstrate a difference between morning light treatment and morning placebo treatment for winter depression [16]; perhaps, the therapeutic effect is from the earlier rising, which is common to both morning light and morning placebo [17]. Similarly, patients arose significantly earlier with the more effective morning light treatment, in two studies comparing morning to evening light treatment for winter depression [18,19].

How early is early, in terms of not exceeding physiologic REM sleep needs and reducing depression risk? Given that REM sleep propensity is more influenced by circadian rhythm than by length of time asleep [11], and that circadian rhythms themselves are powerfully influenced by the light–dark cycle [20], with onset of light after a prolonged dark period (i.e., dawn) likely being the most important "zeitgeber" or timing signal, which plants and animals use to entrain their internal circadian rhythms [21,22], the relationship of rising time to sunrise may be key. In other words, the REM sleep propensity peak is likely coupled to the time of sunrise: the earlier the sun rises in relation to one's usual rising time, the earlier the REM peak would be expected to occur within that person's sleep cycle and the more REM sleep the individual is likely to experience.

Consequently, a direct test of the hypothesized link between rising time and depression would involve prevalence studies in which respondents are asked about habitual arising times. These arising times could then be linked to the timing of dawn at the respondent's geographic location for the time of year being studied. A literature search failed to turn up any such studies reporting depression and arising times.

An alternate test of the hypothesis would involve finding analogues for arising time which apply to populations under study. The time of sunrise, when averaged over a year, may represent such an analogue.

Farmers and other rural dwellers traditionally get up with the sun. In contrast, city dwellers are apt to get up at a specific time of day as dictated by their work or school schedules, rather than by the time of sunrise. Depending on latitude, their arising time may be earlier than sunrise in the winter and well after sunrise in the summertime, even with Daylight Saving Time (DST).

One would therefore expect early rising farmers to be at low risk for REM-induced depression. This is supported by the finding that rural communities have lower prevalences of depressive disorders [23], which vary little from one country to another [24]. Rural suicide rates are also lower than those for urban dwellers in a number of studies [25].

In contrast, for urban populations, one might expect average arising times in relation to average sunrise time (AST), and thus depression rates, to vary from one city to another. For example, in a city with an AST of 7 a.m., a resident who gets up at 6:30 a.m. will be rising on average 30 min *before* sunrise, but at 15 min *after* sunrise in a city with an AST of 6:15 a.m. AST is little influenced by latitude; the most important determinant is how far east or west a city is situated within its time zone. Depending on time zone width, AST can vary by an hour or more from one city to another.

The present hypothesis predicts a correlation between a city's depression prevalence and its AST, assuming that the population samples in each city have comparable arising times by the clock.

To test this hypothesis, a search of the literature was made for studies of depression prevalence, which used comparable methodologies for a number of different (urban) sites, so that an analysis of depression prevalence as a function of AST could be performed. Two such studies were found.

The EURODEP Programme [26] on geriatric depression in nine European centres found striking differences in depression prevalence between cities, for which no satisfactory explanation has so far been found. For example, depressive neurosis prevalences range from 5.3 per hundred for Iceland to 14.4 per hundred for London, United Kingdom.

Similarly, the Epidemiologic Catchment Area (ECA) study [27] examined the prevalence of affective disorder in adults in five US centers. One-year depression prevalences ranged from 1.7 per hundred in Piedmont Country, NC to 3.4 per hundred in New Haven, CT. Again, these marked differences have not been satisfactorily accounted for. The ECA prevalences are much smaller than the EURODEP results, likely a result of the different age categories of respondents as well as different study tools and diagnostic criteria. In the ECA study, trained lay interviewers used a structured questionnaire, the Diagnostic Interview Schedule (DIS), to elicit major depression, dysthymic disorder and bipolar disorder in adults 18 and over according to DSM-III criteria. The EURODEP Programme used a semistructured interview schedule, the Geriatric Mental State (GMS) coupled with a computerized diagnostic algorithm (AGECAT) to elicit depression judged suitable for intervention among randomised samples of those aged 65 and over.

The hypothesis being explored is that in each study, a city's depression prevalence will be predicted by its AST, with later ASTs representing earlier arising times in relation

Table 1
Depressive neurosis prevalence and mean DST sunrise time, EURODEP Programme

EURODEP Programme: centre	Depressive neurosis prevalence (%)	Mean DST sunrise time (h)
Amsterdam, Netherlands	10.1	7.13
Berlin, Germany	10.9	6.56
Dublin, Ireland	11.1	6.87
Iceland[a]	5.3	7.21[b]
Liverpool, United Kingdom	7.2	6.65
London, United Kingdom	14.4	6.47
Munich, Germany	13.0	6.70
Verona, Italy	12.9	6.75
Zaragoza, Spain	6.7	7.55

[a] Mean sunrise time for Iceland's capital, Reykjavik, was used.
[b] Iceland does not use DST.

Table 2
One-year depression prevalence and mean DST sunrise time, ECA study

ECA study: site	One-year depression prevalence (%)[a]	Mean DST sunrise time (h)
New Haven, CT	3.4	6.33
Baltimore, MD	1.9	6.58
St. Louis, MO	2.6	6.49
Piedmont Country, NC[b]	1.7	6.71
Los Angeles, CA	3.2	6.38

[a] Weighted to reflect age, sex and race characteristics of the communities surveyed.
[b] The coordinates for Kittrell, NC were used as the approximate centre of the five counties (Durham, Vance, Franklin, Granville and Warren) in the study.

to sunrise, and therefore less REM sleep, being associated with lower values for depression prevalence.

It has been suggested that the number of daylight hours may influence winter depression, with less light leading to more depression. Accordingly, average daylight hours values were looked at as a possible confounder. Because latitude has been implicated in seasonal affective disorder prevalence [28], although its effect is felt to be small [29,30], it was also included in the analysis.

Method

Sunrise times (when the upper edge of the disk of the sun is on the horizon, considered unobstructed relative to the location of interest), averaged over 1 year, were calculated for each of the ECA and EURODEP centres, as follows: first, for cities outside of the United States, latitude and longitude coordinates were obtained from the GEOnet Names Server [31]. Where more than one set of coordinates for a given city were returned by the server, the set with the designation PPL (Populated Place) was chosen. These coordinates were then used to obtain a table of daily sun rise and set times for the year 1999 from the website of the US Naval Observatory [32]. For cities within the United States, the latter website can return a table when only the city name and the state are provided. Note that the Piedmont Country, NC site consists of five counties, of which one, Durham county, is primarily urban while the other four are predominantly rural. The table for Kittrell, NC, a city at roughly the geographic centre of the five-county area, was used. Also, the Iceland study did not limit itself to a particular city, although those living more than 100 km from Reykjavik were excluded. Accordingly, sunrise data for Reykjavik were used.

Using Microsoft Excel spreadsheet software, the daily sunrise times (in hours and minutes) were first converted to decimal equivalents. An hour was added to each

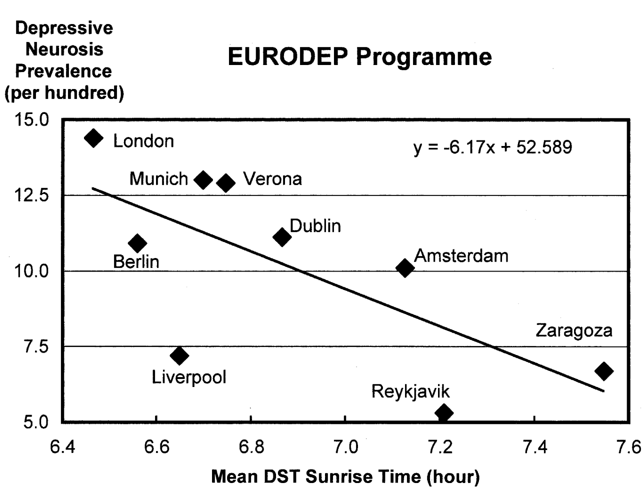

Fig. 1. EURODEP Programme: depressive neurosis prevalence vs. mean DST sunrise time.

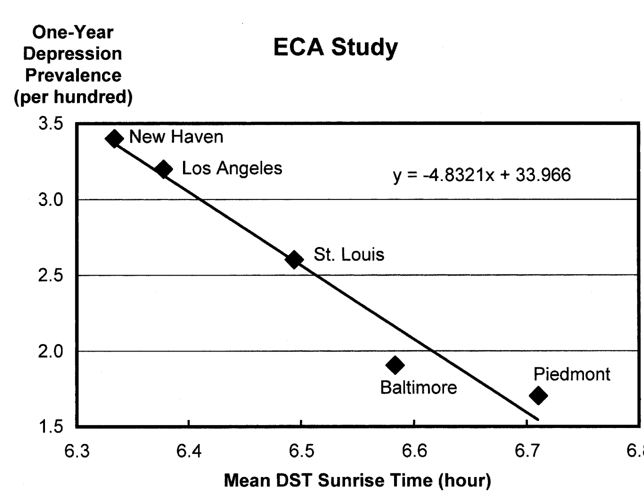

Fig. 2. ECA study: 1-year depression prevalence vs. mean DST sunrise time.

Table 3
Pearson correlations and (regression P values) of depression prevalences vs. sunrise, sunset and daylight; EURODEP Programme

EURODEP Programme	Depressive neurosis	Depressive psychosis	Depression cases	Subcases	Total depression
Mean DST sunrise	− .690 (.0395)	− .222	− .578	− .465	− .629 (.0693, ns)
Median DST sunrise	− .660 (.0532, ns)	− .206	− .549	− .438	− .595 (.0909, ns)
Mean DST sunset	− .767 (.0159)	− .260	− .650 (.0581, ns)	− .515	− .703 (.0346)
Median DST sunset	− .727 (.0266)	− .238	− .611 (.0806, ns)	− .483	− .660 (.0530, ns)
Mean daylight hours	− .526	− .228	− .475	− .346	− .496
Median daylight hours	− .456	− .205	− .416	− .317	− .443
Latitude	− .359	− .315	− .418	− .210	− .383

sunrise and sunset time during the DST period (from the last Sunday in March, 28 March 1999, to the last Saturday in October, 23 October 1999, for the EURODEP cities except for Reykjavik where DST is not used; and from the first Sunday in April, 4 April 1999, to the last Saturday in October for the ECA centres). The means and medians over the entire year were then calculated. These decimal values were then plotted against the neurotic depression prevalence values for the EURODEP Programme and against the 1-year depression prevalence figures for the ECA study.

Correlation coefficients and linear regressions were calculated using DataDesk version 6 software (Data Description Inc.) on a Macintosh computer.

Analyses were also carried out using sunset times, both mean and median, over the year 1999; daylight hours, obtained by subtracting each day's sunrise time from sunset time, both mean and median values over the year 1999; and latitude for each site.

The EURODEP Programme also provided prevalence figures for depressive psychosis and for depression subcases (i.e., AGECAT Levels 1 and 2). The ECA study, in addition to prevalence rates for DSM-III major depression for different time periods (2 weeks, 1 month, 6 months, 1 year and lifetime), gave data for bipolar disorder (for the same time periods) and for lifetime prevalence of dysthymia. These prevalence figures were subjected to the same correlation analyses, with mean and median DST sunrise and sunset times, mean and median daylight hours, and latitude.

Results

The depressive neurosis prevalences from the EURODEP Programme along with corresponding mean DST sunrise times appear in Table 1 and are plotted in Fig. 1, together with the linear regression line. The Pearson product-moment correlation between depressive neurosis prevalence and mean DST sunrise time is − .690 (P=.0395), Kendall $\tau = -.566$, Spearman $\rho = -.667$. Using median DST sunrise time in place of mean DST sunrise time results in a Pearson correlation of − .660 (P=.0532, ns).

One-year depression prevalences from the ECA study and mean DST sunrise times appear in Table 2 and are plotted in Fig. 2. Again, the linear regression line is shown. The Pearson product-moment correlation is − .977 (P=.0041), Kendall $\tau = -1.000$, Spearman $\rho = -1.000$. Substituting median DST sunrise time for mean DST sunrise time results in a Pearson correlation of − .977 (P=.0042).

Correlations of sunrise and sunset times (means and medians), daylight hours (means and medians) and latitude with EURODEP prevalence values for depressive neurosis, depressive psychosis, depression cases (AGECAT Levels 3–5; the sum of depressive neurosis and depressive psychosis), subcases (AGECAT Levels 1 and 2) and total depression (cases + subcases) are found in Table 3. Table 4 gives ECA depression prevalences for five different time frames, correlated with sunrise and sunset times, daylight hours and latitude, while ECA prevalences for bipolar disorder (five time frames) and dysthymia are found in Table 5.

Table 4
Pearson correlations and (regression P values) of depression prevalences vs. sunrise, sunset and daylight; ECA study

ECA study	2-week depression	1-month depression	6-month depression	1-year depression	Lifetime depression
Mean DST sunrise	− .955 (.0116)	− .969 (.0065)	− .981 (.0032)	− .977 (.0041)	− .892 (.0418)
Median DST sunrise	− .961 (.0092)	− .970 (.0062)	− .977 (.0041)	− .977 (.0042)	− .900 (.0375)
Mean DST sunset	− .965 (.0078)	− .974 (.0051)	− .980 (.0034)	− .980 (.0035)	− .904 (.0351)
Median DST sunset	− .941 (.0172)	− .958 (.0103)	− .973 (.0054)	− .965 (.0077)	− .865 (.0582, ns)
Mean daylight hours	.031	.109	.193	.146	− .003
Median daylight hours	.013	.095	.179	.133	− .003
Latitude	.008	.086	.169	.122	− .029

Table 5
Pearson correlations and (regression P values) of bipolar disorder and dysthymia prevalences vs. sunrise, sunset and daylight; ECA study

ECA study	2-week bipolar	1-month bipolar	6-month bipolar	1-year bipolar	Lifetime bipolar	Dysthymia
Mean DST sunrise	− .152	− .222	− .396	− .414	− .699	− .727
Median DST sunrise	− .111	− .168	− .337	− .358	− .657	− .749
Mean DST sunset	− .110	− .168	− .337	− .361	− .658	− .759
Median DST sunset	− .208	− .281	− .452	− .462	− .738	− .692
Mean daylight hours	.615	.783	.887 (.0448)	.806 (.0994, ns)	.692	− .308
Median daylight hours	.602	.784	.891 (.0425)	.823 (.0867, ns)	.684	− .302
Latitude	.618	.780	.880 (.0493)	.795	.677	− .332

Of note are the high correlations between bipolar disorder prevalences and daylight hours as well as latitude, which reach significance for the 6-month time frame.

Discussion

The significant correlations found in both of these studies between depression prevalence and sunrise time, averaged over 1 year, support the hypothesis that later rising times are associated with depression.

As expected, average sunset times, but not average daylight hours, correlate significantly with depression prevalence in both the EURODEP and ECA data. An unexpected finding was the significant correlation between 6-month bipolar disorder prevalence and daylight hours, as well as latitude, in the ECA study, but no correlation to average sunrise or sunset times for bipolar disorder prevalence. Individuals with bipolar disorder are thought to be fundamentally vulnerable to disruptions in circadian rhythms [33] and are already more likely than normals to have disordered daily social rhythms [34] such as the timing of sleep, meals, and social activities. One might posit that at higher latitudes, the wider swings of daylength between winter and summer may exceed the capacity of these individuals to accommodate their individual circadian rhythms to seasonal variation in daylight hours [35]. Thus, the fundamental correlation here would be bipolar disorder prevalence and latitude, with a spurious correlation to daylight hours occurring only because average daylight hours are perfectly correlated with latitude for the five ECA centres (Pearson's $R = 1.000$, $P < .0001$).

While the correlations between depression prevalence and mean sunrise time reached statistical significance for both studies ($P = .0395$ for the EURODEP Programme; $P = .0041$ for the ECA study), it appears that three of the EURODEP centres, Berlin, Liverpool and Iceland are clear outliers. In the case of Iceland, there are several possibilities to explain its very low depression prevalence. Firstly, the study sample in Iceland was mixed urban/rural and rural. Rural populations typically have lower depression prevalences than urban populations [23]. Secondly, Icelanders may have unique genetic characteristics, which reduce their susceptibility to depression [36]. Thirdly, Icelanders eat lots of fish [37] containing antidepressant omega-3 fatty acids [38]. Finally, Iceland is unique among the nine EURODEP centres in not switching to DST during summer months. For individuals who get up by the clock, the switch to DST at the end of October involves suddenly rising 1 h later than before the switch. The present hypothesis suggests that this sudden late rising would acutely increase the amount of REM sleep and could trigger a winter depression. With no DST, Icelanders would have lower rates of winter depression which would result in lower depression prevalences overall.

With respect to the other two outliers, Berlin and Liverpool, other speculations need to be explored; for example, Berliners (and perhaps Germans in general) might be in the habit of starting their days earlier than their neighbours in other European countries. Liverpudlians, even after retirement, may maintain daily social rhythms based on hearing the factory whistle.

The hypothesis that getting up earlier in relation to the sunrise exerts an antidepressant effect might seem counterintuitive. For example, early morning awakening is strongly associated with depressive illness. The present hypothesis suggests that we might reframe early morning awakening as a homeostatic response by the depressed individual to overcome depression, and encourage patients to stay up after waking rather than return to bed. This is consistent with research showing that late partial sleep deprivation is effective against depression [39].

Since the sun rises progressively earlier in comparison with a city dweller's habitual rising time during the spring and summer, the present hypothesis predicts that the (relatively) later rising would result in more REM sleep and therefore more summer depression, a reversal of the actual finding. One explanation might be that a gradual change in sunrise time and in daylight hours permits the organism to adjust its circadian rhythms gradually to the changing seasons [35], in contrast to the sudden changes occurring twice yearly with DST.

The results of the present study, if replicated, predict that the prevalence of depression can be reduced by relatively simple public health measures, such as shifting the boundaries of time zones to the west, going to DST all year round or having factories, offices, stores and schools advance their starting times so that employees and students get up earlier. Eliminating the twice-yearly resetting of the clocks might also be explored as a way to reduce seasonal affective disorder. Cost–benefit ratios for such measures should be extremely favourable, given the significant costs associated with depression, including health care expenditures, absenteeism and decreased productivity.

For example, going to DST all year round, as was done in the United States during both world wars and again in 1973–1974 as an energy saving measure [40], would increase the mean time of sunrise by 0.425 h in North America. Using the slope of the linear regression equation from the ECA study data, this would predict a decrease in depression prevalence of 0.425 times 4.8321, i.e., a reduction of approximately two per hundred. This would theoretically lower New Haven's depression prevalence from 3.4% to 1.4%. Going to DST all year round might also reduce winter depression, which is hypothesized to be triggered by an acute increase in REM sleep occasioned by the switch from DST to standard time at the end of October.

Even better results might be obtained by simply adopting the time zone lying to the east of one's present time zone. For example, the depressive neurosis prevalence for the geriatric population in London would theoretically drop from 14.4 per hundred to 8.3 per hundred, based on a slope of -6.17 for the regression line for all nine centres in the EURODEP study, if Britain were to adopt the time zone used in continental Europe. In the absence of public health initiatives such as the above, individuals might be able to counteract depressive symptoms such as fatigue or lack of energy by simply getting up earlier.

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