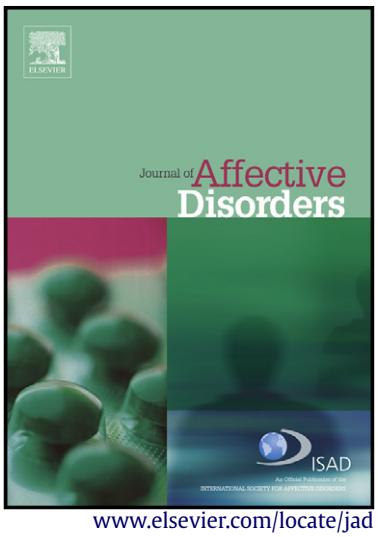

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Relationship between sunlight and the age of onset of bipolar disorder: An international multisite study

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Relationship between sunlight and the age of onset of bipolar disorder: an international multisite study.

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Abstract:

Background: The onset of bipolar disorder is influenced by the interaction of genetic and environmental factors. We previously found that a large increase in sunlight in springtime was associated with a lower age of onset. This study extends this analysis with more collection sites at diverse locations, and includes family history and polarity of first episode.

Methods: Data from 4037 patients with bipolar I disorder were collected at 36 collection sites in 23 countries at latitudes spanning 3.2 north (N) to 63.4 N and 38.2 south (S) of the equator. The age of onset of the first episode, onset location, family history of mood disorders, and polarity of first episode were obtained retrospectively, from patient records and/or direct interview. Solar insolation data were obtained for the onset locations.

Results: There was a large, significant inverse relationship between maximum monthly increase in solar insolation and age of onset, controlling for the country median age and the birth cohort. The effect was reduced by half if there was no family history. The maximum monthly increase in solar insolation occurred in springtime. The effect was one-third smaller for initial episodes of mania than depression. The largest maximum monthly increase in solar insolation occurred in northern latitudes such as Oslo, Norway, and warm and dry areas such as Los Angeles, California.

Limitations: Recall bias for onset and family history data

Conclusions: A large springtime increase in sunlight may have an important influence on the onset of bipolar disorder, especially in those with a family history of mood disorders.

Key words: bipolar disorder, age of onset, sunlight, insolation

1. Introduction

Sunlight provides warmth, stimulates vision, initiates vitamin D synthesis, and plays a fundamental role in how the circadian clock adapts human physiology and behavior to the alternation of day and night (Berson 2003; Brainard and Hanifin, 2005; Hatori and Panda, 2010). Circadian rhythms are involved in regulation of mood (Albrecht 2010; McClung 2013) and abnormalities in circadian rhythms are thought to underlie bipolar disorder (Goodwin and Jamison,1990; Mansour et al., 2005; McClung 2007). We previously found that the larger the springtime increase in solar electromagnetic energy striking the surface of the earth (insolation) at the onset location, the younger the age of onset of bipolar disorder (Bauer et al., 2012).

The emergence of bipolar disorder involves the interaction of complex genetic mechanisms (Burmeister et al., 2008; Craddock and Sklar, 2013; Petronis 2003) and environmental factors (Tsuchiya et al., 2003). Based on 6 studies of 2509 patients with bipolar I disorder, the weighted mean age of onset falls into 3 groups, having peaks at ages 18.1, 26.9 and 42.7 years, with 55% of patients in the middle or late onset groups (Bellivier et al., *2001*; Bellivier et al., 2003; González Pinto et al., 2009; Hamshere et al., 2009; Lin et al., 2006; Manchia et al., 2008). This broad range of onset and the polygenic basis of bipolar disorder suggest that environmental factors have an influential role (Burmeister et al., 2008; Craddock and Sklar, 2013; Wright et al., 2003). Environmental factors associated with a younger age of onset are cannabis use (González-Pinto et al., 2008; Lagerberg et al., 2011), stressful life events (Hoersh et al., *2011*) and childhood abuse (Garno et al., 2005; Leverich et al., 2002), while

neurological illness is associated with an older onset (Depp and Jeste, 2004). The purpose of this study was to repeat our prior investigation of the association between solar insolation and the age of onset of bipolar disorder using a substantially larger sample, and including information on family history and polarity of the first episode.

2. Methods

2.1 Patient data

All patients included in this study had a diagnosis of bipolar disorder according to DSM-IV criteria made by a psychiatrist. Approval for this study was obtained from institutional review boards according to local requirements. Patient data were obtained retrospectively at 36 collection sites in 23 countries. In 20 sites (Athens, Greece; Bangalore, India; Buenos Aires, Argentina; Cagliari, Sardinia, Italy; Dresden, Germany; Halifax, Canada; Helsinki, Finland; Hong Kong; Kansas City, KS, USA; Los Angeles, CA, USA; Medellín, Colombia; Oslo, Norway; Paris, France; Porto Alegre, Brazil; Rochester, MN, USA; San Diego, CA, USA; Santiago, Chile; Siena, Italy; Thessaloniki, Greece; Würzburg, Germany), data were gathered by direct interviews and reviewing records, in 8 sites (Barcelona, Spain; Melbourne/Geelong, Australia; Palo Alto, CA, USA; São Paulo, Brazil; Salvador, Brazil; Trondheim, Norway; Vitoria-Basque Country, Spain; Worcester, MA, USA) primarily by direct interviews, and at the remaining 8 sites (Aarhus, Denmark; Beer Sheva, Israel; Calgary, Canada; Cape Town, South Africa; Kuala Lumpur, Malaysia; Poznan, Poland; Tokyo, Japan; Wiener Neustadt, Austria) primarily by reviewing records.

Variables included sex, date of birth, age of onset, location of onset, family history of any mood disorder in a first degree relative, and polarity of the first episode (depressed, manic or hypomanic). The age of onset was defined as the first occurrence of an episode of depression, mania or hypomania according to DSM-IV criteria.

2.2 Potential confounders

Apart from any solar insolation effects, there were two potential age-related confounders. The country median age varied by about 20 years between the oldest (Japan 45.8 years) and youngest (South Africa at 25.5) collection sites. For a disease with a variable age of onset that spans several decades, an older age of onset would be expected in a country with an older population (Chen et al., 1993; Heimbuch et al., 1980). The country median age was included in all models to reflect the differences in country population.

Previous research reported a large birth cohort effect in bipolar disorder with an older onset in older cohorts (Chengappa et al., 2003), and that less than 10% of people develop bipolar disorder after age 50 (Vasudev and Thomas, 2010). Since the current data includes a large percentage of people born before 1960 (36.8%), three birth cohort groups were created: born before 1940, born between 1940 and 1959, and born after 1959 (Chengappa et al., 2003). The birth cohort grouping variable was included in all models.

There was a large imbalance in the percent of patients with a diagnosis of bipolar I disorder as compared to other bipolar subtypes. Since the percent of bipolar I varied from 23% to 99%, with 40% of collection sites having ≥ 80% of patients with bipolar I disorder, only patients with a diagnosis of bipolar I disorder were included in the analysis.

2.3 Solar Insolation data

All solar insolation data were obtained from the US National Aeronautics and Space Administration (NASA) Surface Meteorology and Solar Energy (SSE) Version 6.0 database, which is based on data collected over a 22 year time period from 1983-2005 (NASA 2012). Average monthly solar insolation data are available for the entire globe with a spatial resolution of 1 x 1 degree latitude/longitude. Solar insolation is a measure of the electromagnetic energy from the sun received for a given surface area on earth at a given time, expressed in kWh/m^2/day (kilowatt hours/square meter/day). Solar insolation is not evenly distributed across the earth's surface. The solar insolation varies with the annual changes to the earth-sun relationship (angle of incidence which the sun's rays strike the earth, the day length, and the latitude), reflection, scattering and absorption of the sun's rays by clouds and aerosols in the atmosphere, and reflection back into space by snow, ice, and desert sand on the earth's surface (NASA 2010).

The overall pattern of monthly changes to solar insolation varies greatly by latitude. At the equator, there is very little change to solar insolation throughout the year. Generally, the closer to the poles, the greater the range in solar insolation across the

year. See Figure 1 for examples of monthly changes in insolation at collection sites in this study. Additionally, locations at the same latitude may have very different solar insolation due to local conditions such as cloud cover, altitude, and proximity to large bodies of water. **For example, Rome, Italy and Chicago IL, US have the same latitude of 41.9 degrees north (N) and the same hours of daylight. However the maximum monthly increase in solar insolation is 1.4 kWh/m^2/day in Rome but only 1.01 kWh/m^2/day in Chicago, occurring between February and March for both cities.**

2.4 Solar insolation variables

Onset location data from every patient were grouped into reference cities. Each reference city represents all locations within the 1 x 1 degree grid of latitude and longitude. For example, Dresden with latitude of 51.1 N and 13.8 degrees east (E) is the reference city for all onset locations between 51 and 52 degrees N, and 13 and 14 degrees E. The monthly solar insolation data for reference cities in the southern hemisphere were shifted by 6 months to be comparable with monthly solar insolation in the northern hemisphere. The number of reference cities from each collection site varied considerably reflecting country size, migration patterns and cultural differences.

Monthly, yearly and seasonal variables were created using the solar insolation data for each reference city including the monthly increase and decrease in solar insolation, the yearly cumulative solar insolation, and the yearly minimum and maximum monthly solar insolation. The interaction between maximum monthly increase in solar insolation x

family history, and maximum monthly increase in solar insolation x polarity of first episode were also analyzed.

2.5 Country specific variables

The variables available for each country for each reference city included the lifetime prevalence of bipolar I disorder, the country median age, and the country sex ratio for ages 15-64 (CIA World Factbook).

2.6 Statistics

Generalized estimating equations (GEE) models were used to estimate the effect of solar insolation on the age of onset. The GEE method corrects for the correlated data within each reference city (cluster) (Zeger and Liang,1986), estimates the difference in magnitude of the association between two variables through the use of interaction terms, and estimates the effect across the entire population rather than within a cluster. All GEE models used age of onset as the dependent variable. An exchangeable correlation matrix was chosen, as appropriate for a large number of clusters with variable cluster sizes including many with a single observation (Stedman et al., 2008; Zeger and Liang, 1986). To further evaluate the birth cohort effect, models were also estimated that excluded both patients born before 1960 and the birth cohort variable. The model fit was assessed using the quasi-likelihood independent model criterion that is suitable for GEE (Pan 2001). A significance level of 0.01 was used to evaluate estimated coefficients. Sidak's adjustment was used to evaluate multiple comparisons at the 0.01 level. SPSS Version 22 was used for all analyses.

3. Results

Data were collected for a total of 5465 patients. Of the 5465 patients, 4037 had a diagnosis of bipolar I disorder, 1236 had bipolar II and 192 had bipolar NOS. Only the 4037 patients with a diagnosis of bipolar I disorder were included in the analysis. The 4037 patients included 2414 from the prior analysis (Bauer et al., *2012*). Of the 4037 patients, 2374 (58.8%) were female and 1663 (41.2%) were male. Family history was available for 3334 (82.6%) of the 4037 patients and polarity of first episode was available for 3600 (89.2%).

The mean age of the patients was 48.1 ± 14.5 years. For comparison with prior international studies, the unadjusted age of onset for the 4037 patients was 25.4 ± 10.7 years, similar to previous reports of 25.7 years, n=1665 (Baldessarini et al., 2012) and 25.6 years, n=1041 (Morselli et al., 2003). Of the 4037 patients, 220 (5.4%) were born before 1940, 1267 (31.4%) were born between 1940 and 1959, and 2550 (63.2%) were born after 1959. As expected, country median age and birth cohort were significantly associated with the age of onset (both $p<0.001$).

Although data for the 4037 patients were collected at 36 collection sites in 23 countries, the onset locations were in 318 unique reference cities or clusters in 43 countries. The onset location was in northern hemisphere for 2994 patients and in the southern hemisphere for 1043 patients. The distribution of the onset locations across latitudes is

shown in Table 1. The mean number of patients in each reference city was 12.7 with 4.3% of the 4037 patients in a reference city of one.

The best fitting model included the interaction of the maximum monthly increase in solar insolation x family history, the country median age and the birth cohort. This is labeled Model 1. The primary result was an inverse relationship between maximum monthly increase in solar insolation and age of onset, which was reduced by about 50% if there was no family history. **To put these results in perspective, when comparing 2 regions with a difference of 0.1 kWh/m^2/day in the maximum monthly increase in solar insolation, the region with the larger increase is associated with a 0.4862 year or nearly 6 months younger age of onset when there is a family history of bipolar disorder, as compared to the region with the smaller increase. If there is no family history, this difference is reduced to 0.2552 year or about 3 months**. There were similar results when Model 1 was run excluding patients born before 1960 and the birth cohort. Model 2 included the interaction of the maximum monthly increase in solar insolation x polarity of first episode, the country median age and the birth cohort, and was also significant. The results also showed the inverse relationship between maximum monthly increase in solar insolation and age of onset, but the effect was about 1/3 smaller for initial episodes of mania. Similar results for Model 2 were also obtained when excluding patients born before 1960 and the birth cohort. See Tables 2 and 3.

The maximum monthly increase in solar insolation occurred in springtime: between February and March in 40% of onset locations, between March and April in 38% of onset locations, and between April and May in 11% of onset locations, excluding the locations near the equator that have little monthly change in solar insolation throughout the year. The maximum increase in solar insolation occurred in diverse latitudes. Table 4 shows the mean age of onset adjusted for country median age and birth cohort by the maximum monthly increase in solar insolation.

The collection site was thought to adequately serve as a proxy for the specific onset location for patients from Barcelona, Cape Town, Helsinki, Melbourne/Geelong, Porto Alegro, São Paulo, Salvador, Vitoria, and Würzburg. The best fitting model was run excluding all these sites and the magnitude of the estimated coefficients did not change substantially and remained significant at the 0.01 level.

The age of onset was also associated with range of monthly solar insolation but the model was not as good a fit as with the maximum monthly increase. As in our prior study, the yearly cumulative solar insolation, the maximum decrease in monthly solar insolation, the yearly minimum and maximum monthly solar insolation, latitude, sex, country prevalence of bipolar I disorder, and country sex ratio were not significantly associated with the age of onset.

4. Discussion

The maximum monthly increase in solar insolation in springtime was inversely associated with the age of onset of bipolar disorder, but this effect was reduced by half in those without a family history of mood disorders. This finding replicated the results of our initial study (Bauer et al., 2012) with a sample that is 67% larger in size and contains 77% more reference cities. The interaction with family history suggests there may be a genetic predisposition to some physiological responses to sunlight, and highlights the importance of obtaining a family history from all patients. This finding is also consistent with many prior reports that family history is associated with a younger age of onset (Baldessarini et al., 2012; Lin et al., 2006; Post et al., 2013; Schürhoff et al., 2000).

Both the collection sites and the onset locations were distributed across all latitudes in both hemispheres, and represent a wide range of solar insolation profiles including arid, sub-arctic, equatorial as well as temperate. In locations that experience a large increase in sunlight in springtime, detailed questioning to detect symptoms of bipolar disorder, and closer monitoring of patients and their adolescent children may be indicated. Conversely, in locations with little change in sunlight throughout the year, the onset of bipolar disorder may be at an older age than expected from studies conducted in temperate climates. The effect of the maximum monthly increase in solar insolation on the age of onset is one-third smaller for those with a first episode of mania rather than depression, in line with prior observation that a first episode of depression occurs at a younger age than mania (Forty et al., 2009; Ortiz et al., 2011; Perlis et al., 2005).

Both longstanding clinical observation of circadian dysfunction in bipolar disorder, and active ongoing research into circadian genes and phenotypes support the concept that a large monthly increase in solar insolation may be associated with disease onset (Goodwin and Jamison 1990; Mansour et al., 2005; McCarthy et al., 2012; McClung 2007; Whybrow 1997). The recent progress in understanding how light changes are unconsciously captured and transmitted to the circadian system (Benarroch 2011; Foster and Hankins, 2007; Hatori and Panda, 2010) may someday help to explain the solar insolation findings in this study. Photosensitive retinal ganglion cells (pRGC) containing the pigment melanopsin mediate a broad range of non-image forming functions including circadian synchronization, melatonin suppression and alertness (Berson 2003, Gooley et al., 2003; Zaidi et al., 2007). The intrinsic photosensitivity of pRGC is specialized to detect fluctuations in intensity of environmental light (Berson 2003, Hatori and Panda, 2010) and the signals are sent to the circadian pacemaker in the suprachiasmatic nucleus (SCN). The peak spectral absorption for non-image forming functions is at short wavelength of visible light, or blue light: ~480 nm for of melanopsin (Berson et al., 2002), ~460 nm for melatonin suppression (Brainard et al., 2001), and ~470 nm for alertness (Stephenson et al., 2012). Similarly, the dominant wavelength of morning sunlight was measured at 477 nm in the US (Gallagher III et al., 1996; Turner and Mainster, 2008).

Although people who live at latitudes with a short daylength have less exposure to solar insolation during winter, indoor lighting is optimized for vision (Andersen et al., 2012;

van Bommel 2006; van Bommel and van den Beld, 2004). In contrast to circadian photoreception, peak absorptions for vision are at longer wavelength: rod-mediated dim light vision at 506 nm or green light, and cone-mediated bright/moderate light vision at 555 nm or green-yellow light (Turner and Mainster, 2008). Standard lighting, such as incandescent, fluorescent warm, and low pressure sodium lamps, has a dominant wavelength of about 575 nm (Bellia et al., 2011) and less than 5% of the intensity of sunlight. However, unlike with vision, insufficient circadian light exposure is not perceived (Turner et al., 2010). There are ongoing efforts to develop new standards for indoor lighting that address circadian as well as visual effects, and will consider the spectrum, intensity, timing of exposure, duration of signal, and ocular physiology (Andersen et al., 2012; Bellia et al., 2011; van Bommel and van den Beld, 2004).

While blue light may be the most important component of solar insolation from a circadian perspective, its role in the emergence of bipolar disorder is not known. The spectral composition of sunlight varies with the time of day, season and latitude (Thorne et al., 2009) and younger people may be particularly sensitive to a springtime increase in blue light. Young eyes only need about half the circadian illuminance as middle aged eyes due to age-related decreases in pupil area and crystalline lens transmission (Turner et al., 2010). In animal studies, abnormal light cycles increased depression-like behavior and impaired learning in normal mice, but not in mice without pRGC (LeGates et al., 2012). Blue light exposure also stimulates cognitive brain activity in normal and blind individuals as detected by fMRI (Stephenson et al., 2012; Vandewalle et al., 2007; Vandewalle et al., 2013). Preliminary studies of patients with seasonal affective

disorder (SAD) found blue light treatment to be more effective than red light (Anderson et al., 2009; Glickman et al., 2006), and that sequence variation in the melanopsin gene may increase vulnerability to SAD (Rocklein et al., 2009).

Other recent evidence supports the importance of a large monthly increase in solar insolation. In patients with depression, there were more early responders to paroxetine when sunlight was increasing during springtime (Tomita et al., 2012). Seasonal variation with an increase in the spring-summer months was reported in the serum concentration of brain-derived-neurotropic factor (BDNF) (Molendkjk et al., 2012) and in serotonin turnover in cerebrospinal fluid (Luykx et al., 2013), and these may be involved in the pathophysiology of depression. Dose dependent suppression of melatonin by light (West et al., 2011) may be exaggerated in bipolar I disorder (Hallam et al., 2009). Vitamin D synthesis in skin requires sunlight exposure. Low vitamin D concentrations were associated with diverse psychiatric disorders (Berk et al., 2008), and by meta-analysis, with depression (Anglin et al., 2013; Annweiler et al., 2013) and poor cognition (Balion et al., 2012). Finally, some patients with depression show anomalies in the retinal response to light (Fountoulakis 2010; Fountoulakis et al., 2005).

4.1 Limitations

There are several limitations to this study. The diagnosis of bipolar disorder was based on the DSM-IV criteria, but the processes of diagnostic assessment and data gathering were not standardized across the collection sites. Self-reported age of onset data are subject to recall bias, however this approach was used in related research (Baldessarini

et al., 2012; Forty et al., 2009; Lin et al., 2006; Perlis et al., 2005). Family history data is often inaccurate and more reliable for severe disorders (Hardt and Franke, 2007), and may be influenced by cultural attitudes towards mental illness (Karasz 2005). Individual exposure to sunlight such as for outdoor workers was not assessed, although most people in industrialized countries work indoors and have indoor hobbies (Godar 2005; Pergams and Zaradic, 2008). This study did not include other environmental factors that may affect the age of onset such as drug abuse, or factors known to disrupt circadian rhythms such as night shift work or irregular lifestyles (Kapczinski et al., 2011; Rosa et al., 2013). Shifting data from the southern hemisphere by six months ignores local cultural dimensions of seasonality.

4.2 Conclusions

In conclusion, the monthly increase in solar insolation may have a significant impact on the age of onset of bipolar disorder, especially in those with a family history of mood disorders. The larger the maximum monthly increase in solar insolation in springtime, the younger the onset of bipolar disorder. A first episode of depression occurred at a younger age than mania, despite the effects of a large springtime increase in solar insolation. Research into the effects of the duration, intensity, timing and wavelength of light is needed in bipolar disorder.

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Table 1. Patient onset location by latitude

Degrees latitude (north and south)*	Number of patients
0-9	309
10-19	200
20-29	286
30-39	1222
40-49	1475
50-59	297
60-69	247
70-79	1
Total	4037

* 1043 in southern hemisphere.

Table 2. Estimated parameter coefficients explaining age of onset with all patients*

				99% Confidence interval		Coefficient significance	
	Parameter	Coefficient estimate	Standard error	Lower	Upper	Wald Chi-square	P
Model 1 N=3334 **							
	Maximum monthly increase in solar insolation	-4.862	1.496	-8.678	-0.973	10.412	0.001
	No family history X maximum monthly increase in solar insolation	2.310	0.311	1.510	3.110	55.271	< 0.001
Model 2 N=3600 ***							
	Maximum monthly increase in solar insolation	-4.948	1.732	-9.409	-0.487	8.161	0.004
	First episode manic X maximum monthly increase in solar insolation	1.663	0.400	0.633	2.694	17.301	< 0.001

* GEE model estimated age of onset using a constant, the country of onset median age, birth cohort groups and the listed parameters with an exchangeable correlation structure in each cluster. The Wald hypothesis test degrees of freedom were 1 for all models.
** 256 onset locations. All Sidak pairwise mean age of onset comparisons for birth cohort and family history were significantly different at the < 0.001 level.
*** 265 onset locations. All Sidak pairwise mean age of onset comparisons for birth cohort and family history were significantly different at the < 0.001 level.

Table 3. Estimated parameter coefficients explaining age of onset with patients born after 1959*

				99% Confidence interval		Coefficient significance	
	Parameter	Coefficient estimate	Standard error	Lower	Upper	Wald Chi-square	P
Model 1 N= 2091 **							
	Maximum monthly increase in solar insolation	-4.623	1.407	-8.247	-0.998	10.792	0.001
	No family history X maximum monthly increase in solar insolation	1.809	0.265	1.127	2.492	46.622	< 0.001
Model 2 N= 2271 ***							
	Maximum monthly increase in solar insolation	-4.880	1.429	-8.561	-1.199	11.661	0.001
	First episode manic X maximum monthly increase in solar insolation	2.213	0.337	1.345	3.081	43.129	< 0.001

* GEE model estimated age of onset using a constant, the country of onset median age and the listed parameters with an exchangeable correlation structure in each cluster. The Wald hypothesis test degrees of freedom were 1 for all models.
** 216 Onset Locations.
*** 223 Onset Locations.

Table 4. Mean adjusted age of onset by maximum monthly increase in solar insolation (kWh/m^2/day) groups

Maximum monthly increase in solar insolation (kWh/m^2/day)	Mean adjusted age of onset	Number of onset reference sites	Number of patients	Percent of patients	Example Locations	Latitude (degrees)
< 0.75	27.53	22	779	19%	Kuala Lumpur, Malaysia Medellin, Columbia Bangalore, India Salvador, Brazil Hong Kong, China Tokyo, Japan	3.17 N 6.29 N 12.98 N 12.98 S 22.25 N 35.69 N
≥ 0.75 and < 1.0	22.47	47	133	3%	Kedah, Malaysia Kolar, India Miami, FL, US Princeton, NJ, US Boston, MA, US	6.13 N 13.13 N 25.78 N 40.35 N 42.35 N
≥ 1.0 and < 1.25	20.97	136	1756	44%	Porto Alegre, Brazil San Diego, CA, US Buenos Aires, Argentina Melbourne, Australia Thessaloniki, Greece Barcelona, Spain Siena, Italy Rochester, MN, US Nova Scotia, Canada Vienna, Austria Paris, France Wurzburg, Germany	30.03 S 32.71 N 34.60 S 37.81 S 40.64 N 41.38 N 43.32 N 44.02 N 45.10 N 48.20 N 48.87 N 49.79 N
≥ 1.25 and < 1.5	20.82	85	707	18%	Beer Sheva, Israel Valparaiso, Chile San Francisco, CA, US	31.25 N 33.05 S 37.78 N

					Sardinia, Italy	39.22 N
					Bordeaux, France	44.83 N
					Calgary, Canada	51.08 N
					Poznan, Poland	51.42 N
≥ 1.5	19.32	28	662	16%	Santiago, Chile	33.45 S
					Cape Town, South Africa	33.92 S
					Los Angeles, CA, US	34.05 N
					Aarhus, Denmark	56.16 N
					Helsinki, Finland	60.18 N
					Trondheim, Norway	63.42 N
Total		318	4037	100%		

Figure 1. Comparison of monthly solar insolation pattern at northern, equatorial and temperate latitudes. The pattern of monthly solar insolation at Helsinki, Finland (60.2 N), San Francisco, CA, US (37.8 N) and Medellin, Columbia (6.3 N).

Conflict of Interest

MB is a consultant for Alkermes, AstraZeneca, BristolMyers Squibb, Ferrer Internacional, Janssen, Lilly, Lundbeck, Otsuka, Servier, Takeda, has received speaker honoraria from AstraZeneca, BristolMyers Squibb, GlaxoSmithKline, Lilly, Lundbeck, Otsuka. Pfizer, and has received grant/research support from The Stanley Medical Research Institute, NARSAD, Deutsche Forschungsgemeinschaft, European Commission (FP7), American Foundation for Suicide Prevention, Bundesministerium für Bildung und Forschung (BMBF). OAA has received speaker honoraria from GSK, Lundbeck, and Otsuka. M Berk has been a speaker for Astra Zeneca, Bristol Myers Squibb, Eli Lilly, Glaxo SmithKline, Janssen Cilag, Lundbeck, Merck, Pfizer, Sanofi Synthelabo, Servier, Solvay and Wyeth, served as a consultant to Astra Zeneca, Bristol Myers Squibb, Eli Lilly, Glaxo SmithKline, Janssen Cilag, Lundbeck Merck and Servier, and has received Grant/Research Support from the NIH, Cooperative Research Centre, Simons Autism Foundation, Cancer Council of Victoria, Stanley Medical Research Foundation, MBF, NHMRC, Beyond Blue, Rotary Health, Geelong Medical Research Foundation, Bristol Myers Squibb, Eli Lilly, Glaxo SmithKline, Meat and Livestock Board, Organon, Novartis, Mayne Pharma, Servier and Woolworths. SD has received advisory board fees and speaker honoraria from Eli Lilly, conference travel support from Servier, and has received Grant/Research Support from the Stanley Medical Research Institute, NHMRC, Beyond Blue, ARHRF, Simons Foundation, Geelong Medical Research Foundation, Fondation FondaMental, Eli Lilly, Glaxo SmithKline, Organon, Mayne Pharma and Servier. AF is/has been a consultant or speaker or has received

research support or has participated in symposia sponsored by Angelini, Astra Zeneca, Bristol-Myers Squibb, Boehringer Ingelheim, Eli Lilly, Janssen, Lundbeck, Mediolanum Pharm, Novartis, Otsuka, Pfizer, and Roche. MAF has received grants from Pfizer, Myriad, National Institute of Mental Health (NIMH), National Institute of Alcohol Abuse and Alcoholism (NIAAA), and the Mayo Foundation, and received travel support from GlaxoSmithKline. AGP has received grants and served as consultant, advisor or CME speaker for Almirall, AstraZeneca, Bristol-Myers Squibb, Cephalon, Eli Lilly, Glaxo-Smith-Kline, Janssen-Cilag, Jazz, Johnson & Johnson, Lundbeck, Merck, Otsuka, Pfizer, Sanofi-Aventis, Servier, Shering-Plough, Solvay, the Spanish Ministry of Science and Innovation (CIBERSAM), the Ministry of Science (Carlos III Institute), the Basque Government, the Stanley Medical Research Institute, and Wyeth. FK has been a member of the board of speakers for Astra-Zeneca, Eli Lilly, Janssen and Servier, a consultant for Servier, and received grants/research support from Astra-Zeneca, Eli Lilly, Janssen-Cilag, Servier, CNPq, CAPES, NARSAD and Stanley Medical Research Institute. UL has received speaker honoraria from AstraZeneca and Lundbeck, has received research grants from Dalhousie University, Halifax, Canada and from the German Federal Ministry of Education and Research. CL has recieved grants from Novartis, Janssen, Covance-Takeda and of COLCIENCIAS and University of Antioquia financial strategy. FGN held a temporary position as an Associate Medical Advisor for Eli Lilly & Co from June 2012 to May 2013. CO served as consultant for Lundbeck, Sunovion, BMS, and has received speaker honoraria from Lundbeck and BMS. AP has received research support from AstraZeneca, and received speaker honoraria from AstraZeneca and Lundbeck. NR is a consultant for Takeda Pharmaceuticals and has

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Contributors

All authors contributed to and approved the final manuscript. Authors MB and TG designed the study. Authors MA, OAA, EA, RA, FB, RHB, MB, TDB, LB, EYWC, MDZ, SD, BE, AF, MAF, KNF, JC, JGF, AGP, HH, SH, CH, AI, ETI, FK, SK, BK, RK, MK, BL, ERL, UL, CLJ, GM, MM, WM, MMC, IM, GM, RM, FGN, CO, YO, AP, DQ, RR, NR, AR, PR, JKR, KS, AMS, CS, DS, SS, AHS, KS, HT, YT, CT, EV, BV, MJW and MZ were involved with data collection. Author TG provided data analysis. Authors MB and TG were involved in the draft manuscript. Author PCW was involved in the initial review.

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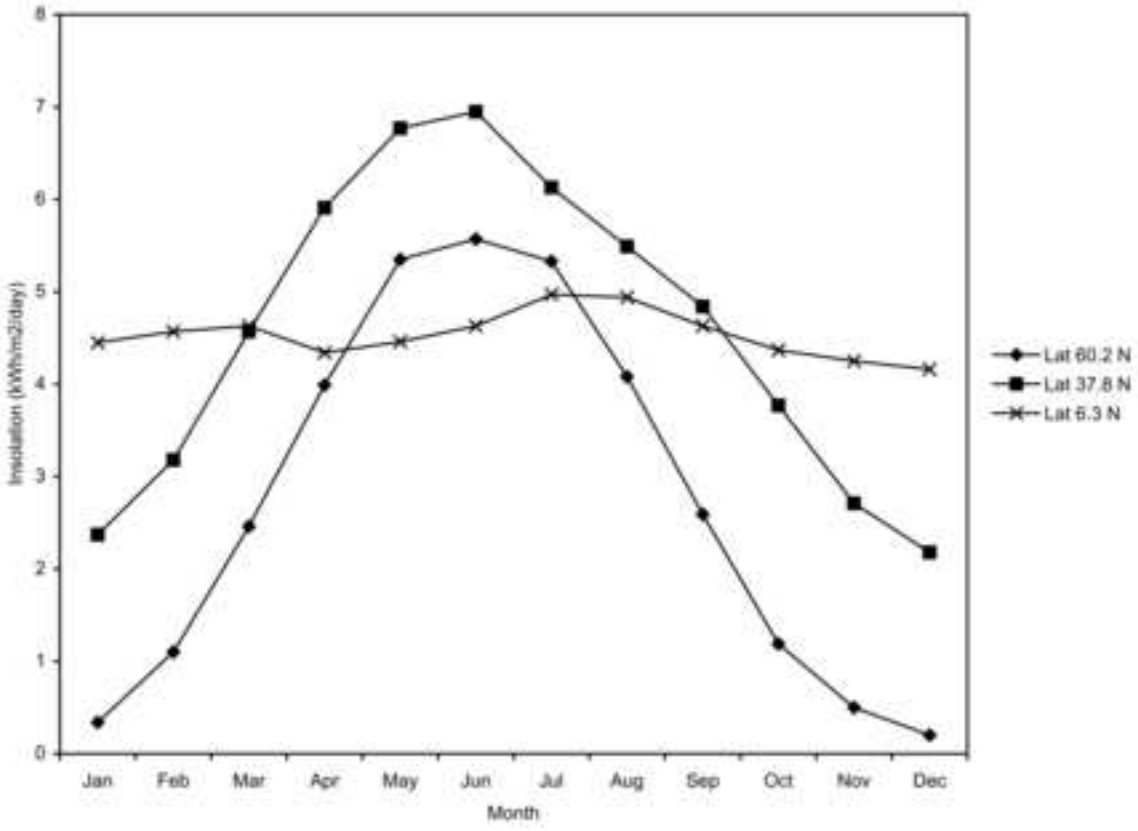
Figure 1. Comparison of monthly solar insolation pattern at northern, equatorial and temperate latitudes. The pattern of monthly solar insolation at Helsinki, Finland (60.2 N), San Francisco, CA, US (37.8 N) and Medellin, Columbia (6.3 N).



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