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ABSTRACT

Objective: Circadian rhythm disruption is commonly observed in bipolar disorder (BD). Daylight is the most powerful signal to entrain the human circadian clock system. This exploratory study investigated if solar insolation at the onset location was associated with the polarity of the first episode of BD I. Solar insolation is the amount of electromagnetic energy from the Sun striking a surface area of the Earth.
Methods: Data from 7488 patients with BD I were collected at 75 sites in 42 countries. The first episode occurred at 591 onset locations in 67 countries at a wide range of latitudes in both hemispheres. Solar insolation values were obtained for every onset location, and the ratio of the minimum mean monthly insolation to the maximum mean monthly insolation was calculated. This ratio is largest near the equator (with little change in solar insolation over the year), and smallest near the poles (where winter insolation is very small compared to summer insolation). This ratio also applies to tropical locations which may have a cloudy wet and clear dry season, rather than winter and summer.
Results: The larger the change in solar insolation throughout the year (smaller the ratio between the minimum monthly and maximum monthly values), the greater the likelihood the first episode polarity was depression. Other associated variables were being female and increasing percentage of gross domestic product spent on country health expenditures. (All coefficients: $P \leq 0.001$).
Conclusion: Increased awareness and research into circadian dysfunction throughout the course of BD is warranted.

1. Introduction

The functions of the circadian clock system are fundamental to human health, and disruptions to circadian rhythms contribute to a wide range of diseases [1–3]. Alterations in circadian rhythms across the lifespan are associated with psychiatric disorders including mood disorders, schizophrenia, anxiety disorders [4–8], and neurodegenerative diseases [9,10]. Patients with bipolar disorder (BD) exhibit symptoms of circadian disruption, such as sleep disturbances, social rhythm alterations and endocrine abnormalities, and these symptoms may persist during remission [11–15]. The consequences of circadian dysfunction in BD may both trigger and exacerbate episodes [16,17]. Dysfunction of circadian clocks may also contribute to the metabolic comorbidity frequently present in patients with psychiatric disorders [18,19].

The human circadian clock system is entrained to the Earth's 24 h rotation using signals from the environment, where daylight is the most powerful signal [20–23]. Daylight has fundamental and extensive effects on the circadian system governing daily human physiology and behavior, including alertness, sleep, mood, stress, cognition, and regulation of neuroendocrine, cardiovascular, and metabolic functions [20,24–30]. Daylight impacts humans through three main routes: vision, skin absorption triggering vitamin D production, and the non-visual responses to light in the retina that drive the circadian clock system. Solar insolation (incoming solar radiation) is defined as the amount of electromagnetic energy from the Sun striking a surface area of the Earth [31]. We previously found a strong, inverse relation between the maximum monthly increase in solar insolation in springtime and the age of onset of BD I [32]. The purpose of this exploratory study was to determine if solar insolation was associated with the polarity of the first episode of BD I, using a large global sample of patient data. The polarity of the first episode affects the time delay to receive a diagnosis of BD [33–36], and has clinically relevant prognostic information [37–41].

2. Methods

2.1. Data collection

Researchers at university medical centers and specialty clinics, as well as individual practitioners, obtained data retrospectively using direct questioning, record review, or both. All patients included in the study had a clinical diagnosis of BD from a psychiatrist according to DSM-IV or DSM-5 criteria. Data were collected between 2010 and 2016 and 2019–2021. Study approval was obtained from local institutional review boards, following local requirements. Participants signed the informed consent before data analysis for this study was initiated. Details about the project methodology were published previously [32,42–44].

2.2. Data collection sites

There were 75 collection sites in 42 countries as shown in Fig. 1. Collection sites located in the northern hemisphere were: Aalborg, Denmark; Aarhus, Denmark; Ankara, Turkey; Athens, Greece; Bangkok, Thailand; Barcelona, Spain; Barhir Dar, Ethiopia; Beer Sheva, Israel; Belgrade, Serbia; Bengaluru, India; Cagliari, Sardinia, Italy (2 sites); Calgary, Canada; Copenhagen, Denmark; Dresden, Germany; Dublin, Ireland; Frankfurt, Germany; Halifax, Canada; Helsinki, Finland; Glasgow, UK; Gothenburg, Sweden; Grand Rapids, MI, USA; Graz, Austria; Groningen, Netherlands; Hong Kong, China; Hyderabad, India; Iowa City, Iowa, USA; Jincheon, South Korea; Kampala, Uganda; Kansas City, KS, USA; Khanti-Mansiysk, Russia; Konya, Turkey; Kuala Lumpur, Malaysia; Los Angeles, CA, USA; Medellín, Colombia; Mexico City, Mexico; Milan, Italy; Oslo, Norway; Ottawa, Canada; Piacenza, Italy; Palo Alto, CA, USA; Paris, France (2 sites); Poznan, Poland; Rochester, MN, USA; Rome, Italy; San Diego, CA, USA; Siena, Italy; Singapore; Stockholm, Sweden; Tartu, Estonia; Thessaloniki, Greece (2 sites); Tokyo, Japan (3 sites); Taichung, Taiwan; Trondheim, Norway; Tunis, Tunisia; Vitoria, Spain; Wardha, India; Wiener Neustadt, Austria; Worcester, MA, USA, and Würzburg, Germany. Collection sites located in the southern hemisphere were: Adelaide, Australia; Melbourne/Geelong, Australia; Buenos Aires, Argentina; Cape Town, South Africa; Christchurch, New Zealand; Mataram, Indonesia; Porto Alegre, Brazil; Salvador, Brazil; Santiago, Chile (2 sites); and São Paulo, Brazil.

2.3. Patient and country data

Data collected for each patient were sex, age of onset, polarity of first episode, family history of mood disorders, history of psychosis, episode course, history of alcohol and substance abuse, and history of suicide attempts. For each patient, three locations were also collected: birth

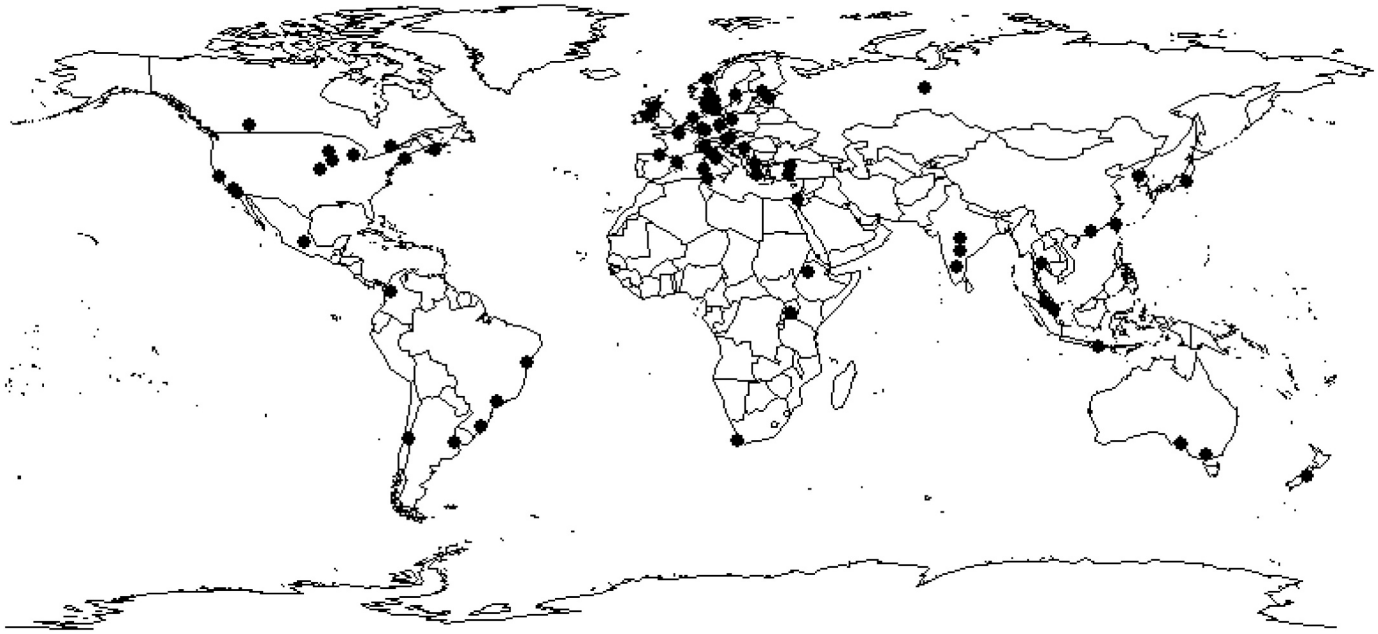

Fig. 1. Location of the 75 international collection sites in 42 countries.

location, onset location and current location.

A variety of country specific socioeconomic data were obtained for all onset locations: physician density per 1000 population, country median age, unemployment rate, poverty rate, gross domestic product (GDP) per capita [45], health expenditure as a percentage of GDP [46], psychiatrists per 100,000 [47], Gini index of income inequality [48], and the gender inequality index [49].

2.4. Solar insolation

The solar insolation values were obtained from the NASA POWER database version 8.0.1, which provides average monthly solar insolation expressed in kilowatt hours/square meter/day (kWh/m^2/day) based on satellite observations collected between 1983 and the present [31]. A 22-year climatology of insolation spanning Jan 1984 - December 2013 at spatial resolution of 1° x 1° latitude/longitude was obtained. The actual patient onset locations were grouped into reference onset locations representing all onset locations within a 1° x 1° grid of latitude and longitude. For each patient, the latitude and longitude of the reference onset location were used to obtain the solar insolation values.

The mean monthly solar insolation received at different latitudes changes throughout the year, with very little change near the equator and extreme changes near the north and south poles. Solar insolation values for locations at the same latitude may also vary considerably due to local conditions such as cloud cover, aerosols (including dust and pollution), water vapor amounts, and altitude. The variance in solar insolation across the year is often considered in terms of changes between the winter months and summer months. However, locations in the tropics (<23.5° north or south of the equator), may have a wet season where clouds reduce solar insolation and a dry season with clear skies rather than a winter/summer insolation pattern. Therefore, to capture the range of solar insolation in tropical as well as non-tropical areas, the ratio of the minimum mean monthly insolation to the maximum mean monthly insolation was created to summarize the changes in solar insolation throughout the year at each reference onset location.

2.5. Statistics

The generalized estimating equations (GEE) statistical technique was used to account for both the correlated data and unbalanced number of patients at reference onset locations. The GEE technique estimates the dependent variable as a function of the entire population, producing a population averaged or marginal estimates of model coefficients [50]. All GEE models in this study were estimated using a binomial distribution, an exchangeable working correlation matrix and a logit link function where the polarity of the first episode (depressed or manic/hypomanic) was the dependent binary variable. To identify the best model, the multivariate model estimates were compared using the corrected quasi-likelihood independence model criterion [51] and confidence intervals at the 0.01 significance level to reduce the chance of type 1 errors. Based on the logit link function, the exponentiated coefficient can be interpreted as the effect size [52]. Demographic variables were reported using descriptive statistics. SPSS version 26.0 was used for all analyses. The R software was used to create Fig. 1 [53].

3. Results

Data were available for 11,063 patients with BD, of which 8080 had a diagnosis of BD I. Of the 8080 patients, 7488 (92.7%) had all the variables in the best model and were included in the analysis. The demographics of the 7488 patients are shown in Table 1. Of the 7488 patients, 4366 (58.3%) were female, and the polarity of the first episode was depressed for 3743 (50%). The mean age of onset for the 7488 patients was 25.6 ± 10.7 years, similar to other international studies [54–56]. For the 7488 patients, there were 591 reference onset locations in 67 countries at a wide range of latitudes in both hemispheres. The average number of patients at each onset location was 12.7, with 285 onset locations having a single patient. Of the 7488 patients, 1685 (22.5%) had an onset location in the tropics, and 1576 (21%) had an onset location in the southern hemisphere.

Table 1
Demographics of patients with BD I[1] ($N = 7488$).

Parameter	Value	N	%
Sex			
	Female	4366	58.3
	Male	3122	41.7
Polarity of first episode			
	Manic/ Hypomanic	3745	50.0
	Depressed	3743	50.0
Family history of mood disorder			
	No	3179	47.7
	Yes	3492	52.3
Alcohol or substance abuse			
	No	3677	69.1
	Yes	1645	30.9
History of psychosis			
	No	2146	35.7
	Yes	3859	64.3
Comorbid anxiety/panic/ OCD			
	No	4017	76.6
	Yes	995	23.4

Parameter	Mean	SD
Health expenditures as percent of country GDP	8.6	2.7
Age of onset	25.5	10.5

[1] Missing values excluded.

3.1. Model estimate

The best fitting model estimated the percentage of patients with a first episode of depression using an intercept, the ratio of the minimum mean monthly insolation to the maximum mean monthly insolation for the reference onset location, sex, and the country health expenditure as a percentage of GDP. See Table 2. The estimated coefficients for the best model suggest that the odds of first episode of depression decrease by 6.7% for every 0.1 increase in the ratio of minimum mean monthly insolation to maximum mean monthly insolation. Alternatively stated, comparing a ratio of 1 (near the equator) to a ratio of 0 (near a pole), there was a 67% difference in the odds of a first episode of depression with the lowest odds at the equator. The model estimates that being female will increase the odds of a first episode of depression by 47% and a 1% increase in country health expenditure as a percentage of GDP will increase the odds of a first episode of depression by 7%. The best model included 92.7% of the collected data.

The ratio of the minimum mean monthly insolation to the maximum mean monthly insolation, solar insolation varied between the extremes of 0.0 near the north pole and 0.89 near the equator. See Table 3. The current health expenditure as a percentage of GDP for the year 2018 varied between the extremes of 2.9% and 16.9% of GDP. The other patient variables, solar insolation variables and country variables considered were not significant or the models were not as meaningful.

Table 2
Estimated parameters explaining the polarity of the first episode for patients with BD I (N = 7488)[1].

Parameters	Coefficient estimate (β)	Standard Error	Exp (β)	99% Confidence Interval		Coefficient Significance	
				Lower	Upper	Wald Chi-squared	P
Intercept	−0.646	0.1885	0.524	−1.016	−0.277	11.745	0.001
Ratio of monthly mean minimum/monthly mean maximum insolation	−1.109	0.2803	0.330	−1.658	−0.559	15.645	< 0.001
Sex - Female	0.338	0.0540	1.474	0.282	0.494	51.618	< 0.001
Country health expenditure as percentage of GDP	0.075	0.0146	1.077	0.046	0.103	25.945	< 0.001

[1] Dependent variable: Polarity of first episode depressed (yes/no). Model: intercept, ratio of monthly mean minimum/monthly mean maximum insolation at onset location, female (yes/no), country health expenditure as percentage of GDP.

Table 3
Ratio of monthly mean minimum/monthly mean maximum insolation: example onset locations by latitude group.

Degrees Latitude North + South	Onset Location	Ratio of Monthly Mean Minimum/Monthly Mean Maximum Insolation
0–-9	Kampala, Uganda	0.8197
	Kuala Lumpur, Malaysia	0.7694
	Mataram, Indonesia	0.7831
	Medellín, Columbia	0.8370
	Singapore	0.7797
10–-19	Bahir Dar, Ethiopia	0.7713
	Bangkok, Thailand	0.7207
	Bengaluru, India	0.6814
	Hyderabad, India	0.6421
	Mexico City, Mexico	0.6855
	Salvador, Brazil	0.6246
20–-29	Hong Kong, China	0.6016
	São Paulo, Brazil	0.6050
	Taichung, Taiwan	0.3931
	Wardha, India	0.5750
30–-39	Ankara, Turkey	0.2374
	Athens, Greece	0.2319
	Beer Sheva, Israel	0.3556
	Buenos Aires, Argentina	0.3149
	Cagliari, Italy	0.2328
	Cape Town, South Africa	0.3227
	Los Angeles, CA, USA	0.3503
	Melbourne, Australia	0.2913
	San Francisco, CA, USA	0.3137
	Santiago, Chile	0.2879
	Seoul, South Korea	0.4404
	Tokyo, Japan	0.5574
	Tunis, Tunisia	0.2859
40–-49	Belgrade, Serbia	0.1960
	Barcelona, Spain	0.2603
	Boston, MA, USA	0.2662
	Christchurch, New Zealand	0.2461
	Grand Rapids, MI, USA	0.2256
	Halifax, Canada	0.2270
	Minneapolis, MN, USA	0.2371
	Paris, France	0.1540
	Rome, Italy	0.2203
	Siena, Italy	0.2077
	Vienna, Austria	0.1667
	Würzburg, Germany	0.1477
50–-59	Aarhus, Denmark	0.0782
	Calgary, Canada	0.1454
	Dresden, Germany	0.1379
	Dublin, Ireland	0.1149
	Oslo, Norway	0.0433
	Poznan, Poland	0.1290
	Stockholm, Sweden	0.0427
	Tartu, Estonia	0.0562
60+	Helsinki, Finland	0.0359
	Khanti-Mansiysk, Russia	0.0243
	Trondheim, Norway	0.0116

4. Discussion

The primary finding of this study was that increasing change in solar insolation during the year was associated with a first episode of depression in patients with BD I. The larger the change in solar insolation throughout the year at the onset location, the greater the likelihood that the polarity of the first episode was depressed. For patients living outside the tropics, the largest change in solar insolation is between winter and summer, with extreme change near the poles. For those living in the tropics, the largest change is between the wet and dry season. Approximately 20% of those with major depressive episodes will develop the defining manic or hypomanic episodes of BD, although estimates vary widely [57–59]. Hypothetically, this study suggests that solar insolation could be an environmental factor associated with the transition from major depressive disorder (MDD) to BD. When treating patients with a first episode of depression, physicians in locations with a large change in solar insolation across the year should monitor even more carefully for BD.

The human circadian clock system is organized in a hierarchical manner with a master clock in the suprachiasmatic nuclei (SCN) of the hypothalamus that coordinates with the peripheral clocks found in virtually all tissues and cells [1,60,61]. The master clock is entrained to the environment primarily by light changes perceived in the retina and sent to the SCN, which coordinates the circadian activities of other brain areas and the peripheral clocks using neural and neuroendocrine signals. The effects of light are related to the spectral properties, timing, duration and pattern of light exposure, and individual characteristics including age, sex, genetics, ocular health, general health, and lifestyles [20,21,28,62]. Disruptions in circadian rhythms can be defined as misalignment in biological timing between different levels of the circadian clock system, or as misalignment with the environmental light/dark cycle [63,64]. Many symptoms of circadian rhythm disruption are documented in BD, including irregular sleep-wake cycles, abnormal melatonin secretion, evening chronotype, supersensitivity to phase delaying effects of light, metabolic dysregulation, and irregular social rhythms [11,12,15,65,66]. Circadian rhythm disruption may result in mitochondrial dysfunction and contribute to the pathogenesis of BD [67,68]. Circadian rhythm disruption may also contribute to the high rate of comorbid substance use disorders reported in international studies [69,70], and substance use in turn induces changes in circadian rhythms that may exacerbate addiction [71–73]. In a sample with data from 193 countries, fewer hours of sunlight and colder weather were associated with increased alcohol consumption and alcoholic cirrhosis [74]. In prior analysis of this sample, a larger change in solar insolation across the year was associated with an increasing risk of suicide attempts [44,75].

In this study, females were at increased risk for a first episode of depression, which is consistent with some prior research [38,39,76,77]. However, review articles addressing the identification of individual risk factors associated with transition from unipolar to BD, such as family history, sex, and early age of onset, report only limited agreement among studies [58,78,79]. There are difficult clinical challenges in assessing if a first episode of depression is due to BD rather than MDD [33,80–82]. Many patients with BD are initially diagnosed with MDD, often with a 6–10 year delay before the correct diagnosis is determined and optimal treatment is started [36,83–85]. There is widespread agreement on the need to improve recognition of those at-risk for BD,

with approaches to include neuroimaging and genetic studies [33,82,86]. Differences in symptoms of circadian rhythm dysfunction may also help to differentiate between MDD and BD, with more severe symptoms of circadian dysfunction generally associated with BD [15,87,88]. Individual differences in chronobiological characteristics may also contribute to the heterogeneity in clinical presentation across the bipolar spectrum [89]. The results of this study suggest a need to increase routine awareness of circadian dysfunction.

Another finding in this study was that an increasing percentage of GDP spent on country health expenditures was associated with increasing risk of a first episode of depression. Given that depression is not a disease of affluence [90], we assume that some patients with depression remain undiagnosed and untreated in countries with less funding available for mental healthcare [91,92]. Other socioeconomic conditions and aspects of modern lifestyles may lead to circadian disruption. Many employees have unpredictable work schedules that include shift work, rotating shifts, and variable hours on short notice [93,94], situations that may cause circadian misalignment [95]. In the US, in a nationally representative survey of early career workers in hourly jobs, 41% learned their work hours one week in advance or less [96]. Another important societal change is the worldwide conversion to light-emitting diodes (LED) technology as the dominant lighting source for indoor and outdoor general illumination, and to backlight digital technology. LED lighting directly affects the non-visual response to light in the retina, and may cause circadian rhythm disruption [97–100]. Studies of children and adolescents find a high use of digital devices before bedtime, which is associated with negative effects on sleep timing and quality [101,102]. In a nationally representative study of adolescents in the US, increasing levels of artificial light at night were associated with less favorable sleep patterns, and with mood and anxiety disorders [103]. Young adults may be more vulnerable to the effects of sleep loss and circadian disruption than older adults [104]. Outdoor light pollution at night from high intensity LED streetlights may also cause circadian disruptions [105].

The results of this study highlight the need to better understand the role of circadian dysfunction in BD. Knowledge of chronobiology is growing rapidly, but the systems are very complex, such as the non-visual retinal functions and underlying genetics [62,106–108]. Additionally, there is considerable individual variation in the major measurements used in chronobiology [62,63,109]. Examples include a normal distribution of chronotypes across a population [110], and a 50-fold range in sensitivity to evening light measured by melatonin suppression across healthy young adults [111]. Increased knowledge of circadian entrainment in real world settings involving both daylight and LED lighting is also needed [26,62,106], and will help to clarify circadian dysfunction throughout the course of BD.

4.1. Limitations

There are limitations to this exploratory analysis. A seasonal analysis was not completed due to the inclusion of both tropical and non-tropical locations in the dataset. In other research, a seasonal pattern was found in about one-fourth of patients with BD, occurring more frequently in BD II [112,113]. Although the diagnosis was based on the DSM-IV or DSM-5 criteria, the process of data gathering was not standardized across collection sites. To maximize participation in the project, only minimal clinical data were collected for each patient. The length of time for a patient to receive the diagnosis of BD, or if a patient initially received an incorrect diagnosis were not available. There may be recall bias in self-reported episode polarity, especially if undiagnosed, untreated, and in early life. Episodes with mixed features were not analyzed separately. This study includes only patients with BD, and cannot estimate the rate of transition from MDD. There was also no individual data on lifestyles including shift work, sun exposure, sun related activities, technology use, or retinal abnormalities. There was large variation in the number of reference onset locations from the collection sites, related to country size, migration patterns, and cultural factors. Cross-cultural differences in the expression of depressive symptoms and societal responses were not considered [114,115]. The sample was not demographically representative of the country populations. In this study 21% of the patients had an onset in the southern hemisphere, but it is estimated that about 12.5% of the world's population lives in the southern hemisphere [116]. Outdoor artificial light at night was not evaluated [117]. Perinatal light exposure may influence future circadian resilience, but no individual data were available on this [118,119]. There was insufficient patient data to consider regional variance in solar insolation that has occurred over decadal timeframes.

4.2. Conclusions

In patients with BD I, increasing change in solar insolation during the year, between winter and summer or tropical wet and dry seasons, was associated with a first episode with a polarity of depression. Physicians who practice in locations with a large change in solar insolation across the year should monitor even more carefully for BD. Increased awareness and research into the role of circadian dysfunction throughout the course of BD is needed.

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Declaration of Competing Interest

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References

[1] R. Allada, J. Bass, Circadian mechanisms in medicine, N. Engl. J. Med. 384 (2021) 550–561, https://doi.org/10.1056/NEJMra1802337.
[2] S. Panda, The arrival of circadian medicine, Nat. Rev. Endocrinol. 15 (2019) 67–69, https://doi.org/10.1038/s41574-018-0142-x.
[3] T. Roenneberg, M. Merrow, The circadian clock and human health, Curr. Biol. 26 (2016) R432–R443, https://doi.org/10.1016/j.cub.2016.04.011.
[4] A. Jagannath, S.N. Peirson, R.G. Foster, Sleep and circadian rhythm disruption in neuropsychiatric illness, Curr. Opin. Neurobiol. 23 (2013) 888–894, https://doi.org/10.1016/j.conb.2013.03.008.
[5] R.W. Logan, C.A. McClung, Rhythms of life: circadian disruption and brain disorders across the lifespan, Nat. Rev. Neurosci. 20 (2019) 49–65, https://doi.org/10.1038/s41583-018-0088-y.
[6] W.H. Walker 2nd, J.C. Walton, A.C. DeVries, R.J. Nelson, Circadian rhythm disruption and mental health, Transl. Psychiatry 10 (2020) 28, https://doi.org/10.1038/s41398-020-0694-0.
[7] A. Wirz-Justice, F. Benedetti, Perspectives in affective disorders: clocks and sleep, Eur. J. Neurosci. 51 (2020) 346–365, https://doi.org/10.1111/ejn.14362.
[8] N.J. Yates, Schizophrenia: the role of sleep and circadian rhythms in regulating dopamine and psychosis, Rev. Neurosci. 27 (2016) 669–687, https://doi.org/10.1515/revneuro-2016-0030.
[9] Y. Leng, E.S. Musiek, K. Hu, F.P. Cappuccio, K. Yaffe, Association between circadian rhythms and neurodegenerative diseases, Lancet Neurol. 18 (2019) 307–318, https://doi.org/10.1016/S1474-4422(18)30461-7.
[10] A. Videnovic, A.S. Lazar, R.A. Barker, S. Overeem, 'The clocks that time us'–circadian rhythms in neurodegenerative disorders, Nat. Rev. Neurol. 10 (2014) 683–693, https://doi.org/10.1038/nrneurol.2014.206.

[11] S. Dallaspezia, F. Benedetti, Alteration in circadian rhythms in bipolar disorder: Mechanisms and implications, in: J. Quevedo, A.F. Carvalho, E. Vieta (Eds.), Neurobiology of Bipolar Disorder: Road to Novel Therapeutics, Academic Press, 2021, pp. 117–128. https://www.sciencedirect.com/science/article/pii/B9780128191828000107.

[12] R. Gonzalez, The relationship between bipolar disorder and biological rhythms, J. Clin. Psychiatry 75 (2014) e323–e331, https://doi.org/10.4088/JCP.13r08507.

[13] N. Meyer, S.M. Faulkner, R.A. McCutcheon, T. Pillinger, D.J. Dijk, J.H. MacCabe, Sleep and circadian rhythm disturbance in remitted schizophrenia and bipolar disorder: a systematic review and meta-analysis, Schizophr. Bull. 46 (2020) 1126–1143, https://doi.org/10.1093/schbul/sbaa024.

[14] T.H. Ng, K.F. Chung, F.Y. Ho, W.F. Yeung, K.P. Yung, T.H. Lam, Sleep-wake disturbance in interepisode bipolar disorder and high-risk individuals: a systematic review and meta-analysis, Sleep Med. Rev. 20 (2015) 46–58, https://doi.org/10.1016/j.smrv.2014.06.006.

[15] Y. Takaesu, Circadian rhythm in bipolar disorder: a review of the literature, Psychiatry Clin. Neurosci. 72 (2018) 673–682, https://doi.org/10.1111/pcn.12688.

[16] P.A. Geoffroy, Clock genes and light signaling alterations in bipolar disorder: when the biological clock is off, Biol. Psychiatry 84 (2018) 775–777, https://doi.org/10.1016/j.biopsych.2018.09.006.

[17] A.G. Harvey, Sleep and circadian rhythms in bipolar disorder: seeking synchrony, harmony, and regulation, Am. J. Psychiatry 165 (2008) 820–829, https://doi.org/10.1176/appi.ajp.2008.08010098.

[18] R. Barandas, D. Landgraf, M.J. McCarthy, D.K. Welsh, Circadian clocks as modulators of metabolic comorbidity in psychiatric disorders, Curr. Psychiatry Rep. 17 (2015) 98, https://doi.org/10.1007/s11920-015-0637-2.

[19] C. Calkin, C. McClelland, K. Cairns, L. Kamintsky, A. Friedman, Insulin resistance and blood-brain barrier dysfunction underlie neuroprogression in bipolar disorder, Front. Psychiatry 12 (2021), 636174, https://doi.org/10.3389/fpsyt.2021.636174.

[20] R.G. Foster, Fundamentals of circadian entrainment by light, Light. Res. Technol. 53 (2021) 377–393, https://doi.org/10.1177/14771535211014792.

[21] A.S. Prayag, M. Münch, D. Aeschbach, S.L. Chellappa, C. Gronfier, Light modulation of human clocks, wake, and sleep, Clocks Sleep 1 (2019) 193–208, https://doi.org/10.3390/clockssleep1010017.

[22] T. Roenneberg, C.J. Kumar, M. Merrow, The human circadian clock entrains to sun time, Curr. Biol. 17 (2007) R44–R45, https://doi.org/10.1016/j.cub.2006.12.011.

[23] K.P. Wright Jr., A.W. McHill, B.R. Birks, B.R. Griffin, T. Rusterholz, E.D. Chinoy, Entrainment of the human circadian clock to the natural light-dark cycle, Curr. Biol. 23 (2013) 1554–1558, https://doi.org/10.1016/j.cub.2013.06.039.

[24] S. Crnko, B.C. Du Pré, J.P.G. Sluijter, L.W. Van Laake, Circadian rhythms and the molecular clock in cardiovascular biology and disease, Nat. Rev. Cardiol. 16 (2019) 437–447, https://doi.org/10.1038/s41569-019-0167-4.

[25] C.B. Green, J.S. Takahashi, J. Bass, The meter of metabolism, Cell 134 (2008) 728–742, https://doi.org/10.1016/j.cell.2008.08.022.

[26] M. Knoop, O. Stefani, B. Bueno, B. Matusiak, R. Hobday, A. Wirz-Justice, et al., Daylight: what makes the difference? Light. Res. Technol. 52 (2020) 423–442, https://doi.org/10.1177/1477153519869758.

[27] T.A. LeGates, D.C. Fernandez, S. Hattar, Light as a central modulator of circadian rhythms, sleep and affect, Nat. Rev. Neurosci. 15 (2014) 443–454, https://doi.org/10.1038/nrn3743.

[28] M. Münch, A.E. Brøndsted, S.A. Brown, A. Gjedde, T. Kantermann, K. Martiny, et al., The effect of light on humans, in: Changing Perspectives on Daylight: Science, Technology, and Culture, Science/AAAS, Washington, DC, 2017, pp. 16–23. https://www.science.org/content/resource/changing-perspectives-daylight-science-technology-and-culture.

[29] S. Paul, T. Brown, Direct effects of the light environment on daily neuroendocrine control, J. Endocrinol. (2019), https://doi.org/10.1530/JOE-19-0302. JOE-19-0302.R1.

[30] A. Wirz-Justice, D.J. Skene, M. Münch, The relevance of daylight for humans, Biochem. Pharmacol. 191 (2021), 114304, https://doi.org/10.1016/j.bcp.2020.114304.

[31] NASA, The Power Project. https://power.larc.nasa.gov/, 2021 (accessed 12 March 2022).

[32] M. Bauer, T. Glenn, M. Alda, M.A. Aleksandrovich, O.A. Andreassen, E. Angelopoulos, et al., Solar insolation in springtime influences age of onset of bipolar I disorder, Acta Psychiatr. Scand. 136 (2017) 571–582, https://doi.org/10.1111/acps.12772.

[33] M. Bauer, O.A. Andreassen, J.R. Geddes, L. Vedel Kessing, U. Lewitzka, T. G. Schulze, et al., Areas of uncertainties and unmet needs in bipolar disorders: clinical and research perspectives, Lancet Psychiatry 5 (2018) 930–939, https://doi.org/10.1016/S2215-0366(18)30253-0.

[34] B. Cha, J.H. Kim, T.H. Ha, J.S. Chang, K. Ha, Polarity of the first episode and time to diagnosis of bipolar I disorder, Psychiatry Investig. 6 (2009) 96–101, https://doi.org/10.4306/pi.2009.6.2.96.

[35] J. Dagani, G. Signorini, O. Nielssen, M. Bani, A. Pastore, G. Girolamo, et al., Meta-analysis of the interval between the onset and management of bipolar disorder, Can. J. Psychiatr. 62 (2017) 247–258, https://doi.org/10.1177/0706743716656607.

[36] N. Drancourt, B. Etain, M. Lajnef, C. Henry, A. Raust, B. Cochet, et al., Duration of untreated bipolar disorder: missed opportunities on the long road to optimal treatment, Acta Psychiatr. Scand. 127 (2013) 136–144, https://doi.org/10.1111/j.1600-0447.2012.01917.x.

[37] C. Daban, F. Colom, J. Sanchez-Moreno, M. García-Amador, E. Vieta, Clinical correlates of first-episode polarity in bipolar disorder, Compr. Psychiatry 47 (2006) 433–437, https://doi.org/10.1016/j.comppsych.2006.03.009.

[38] L. Forty, L. Jones, I. Jones, D.J. Smith, S. Caesar, C. Fraser, et al., Polarity at illness onset in bipolar I disorder and clinical course of illness, Bipolar Disord. 11 (2009) 82–88, https://doi.org/10.1111/j.1399-5618.2008.00654.x.

[39] R.H. Perlis, M.P. Delbello, S. Miyahara, S.R. Wisniewski, G.S. Sachs, A. A. Nierenberg, et al., Revisiting depressive-prone bipolar disorder: polarity of initial mood episode and disease course among bipolar I Systematic Treatment Enhancement Program for bipolar disorder participants, Biol. Psychiatry 58 (2005) 549–553, https://doi.org/10.1016/j.biopsych.2005.07.029.

[40] L.N. Yatham, M. Kauer-Sant'Anna, D.J. Bond, R.W. Lam, I. Torres, Course and outcome after the first manic episode in patients with bipolar disorder: prospective 12-month data from the Systematic Treatment Optimization Program For Early Mania project, Can. J. Psychiatr. 54 (2009) 105–112, https://doi.org/10.1177/070674370905400208.

[41] M. Yoldi-Negrete, A. Fresán-Orellana, M. Jiménez-Tirado, S. Martínez-Camarillo, L. Palacios-Cruz, E. Vieta, et al., Ten-year course of treated bipolar I disorder: the role of polarity at onset, Brain Behav. 11 (2021), e2279, https://doi.org/10.1002/brb3.2279.

[42] M. Bauer, T. Glenn, M. Alda, O.A. Andreassen, R. Ardau, F. Bellivier, et al., Impact of sunlight on the age of onset of bipolar disorder, Bipolar Disord. 14 (2012) 654–663, https://doi.org/10.1111/j.1399-5618.2012.01025.x.

[43] M. Bauer, T. Glenn, M. Alda, O.A. Andreassen, E. Angelopoulos, R. Ardau, et al., Relationship between sunlight and the age of onset of bipolar disorder: an international multisite study, J. Affect. Disord. 167 (2014) 104–111, https://doi.org/10.1016/j.jad.2014.05.032.

[44] M. Bauer, T. Glenn, E.D. Achtyes, M. Alda, E. Agaoglu, K. Altınbaş, et al., Variations in seasonal solar insolation are associated with a history of suicide attempts in bipolar I disorder, Int. J. Bipolar Disord. 9 (2021) 26, https://doi.org/10.1186/s40345-021-00231-7.

[45] CIA, The World Factbook. https://www.cia.gov/the-world-factbook/, 2021 (accessed 12 March 2022).

[46] WHO, Global Health Expenditure Database. https://apps.who.int/nha/database, 2021 (accessed 12 March 2022).

[47] WHO, Human Resources Data By Country. https://apps.who.int/gho/data/node.main.MHHR?lang=en, 2019 (accessed 12 March 2022).

[48] World Bank, Gini Index (World Bank estimate). https://data.worldbank.org/indicator/SI.POV.GINI, 2020 (accessed 12 March 2022).

[49] UN, Gender Inequality Index (GII). http://hdr.undp.org/en/content/gender-inequality-index-gii, 2020 (accessed 12 March 2022).

[50] S.L. Zeger, K.Y. Liang, Longitudinal data analysis for discrete and continuous outcomes, Biometrics 42 (1986) 121–130, https://doi.org/10.2307/2531248.

[51] W. Pan, Akaike's information criterion in generalized estimating equations, Biometrics 57 (2001) 120–125, https://doi.org/10.1111/j.0006-341x.2001.00120.x.

[52] F. Li, A.B. Forbes, E.L. Turner, J.S. Preisser, Power and sample size requirements for GEE analyses of cluster randomized crossover trials, Stat. Med. 38 (2019) 636–649, https://doi.org/10.1002/sim.7995.

[53] R.A. Becker, A.R. Wilks, R. Brownrigg, Maps: draw geographical maps. R 4.1.1, (package version 3.4.0). https://cran.r-project.org/web/packages/maps/maps.pdf, 2021.

[54] R.J. Baldessarini, L. Tondo, G.H. Vazquez, J. Undurraga, L. Bolzani, A. Yildiz, et al., Age at onset versus family history and clinical outcomes in 1,665 international bipolar-I disorder patients, World Psychiatry 11 (2012) 40–46, https://doi.org/10.1016/j.wpsyc.2012.01.006.

[55] J.L. Kalman, S. Papiol, A.J. Forstner, U. Heilbronner, F. Degenhardt, J. Strohmaier, et al., Investigating polygenic burden in age at disease onset in bipolar disorder: findings from an international multicentric study, Bipolar Disord. 21 (2019) 68–75, https://doi.org/10.1111/bdi.12659.

[56] P.L. Morselli, R. Elgie, GAMIAN-Europe, GAMIAN-Europe/BEAM survey I–global analysis of a patient questionnaire circulated to 3450 members of 12 European advocacy groups operating in the field of mood disorders, Bipolar Disord. 5 (2003) 265–278, https://doi.org/10.1034/j.1399-5618.2003.00037.x.

[57] J.G. Fiedorowicz, J. Endicott, A.C. Leon, D.A. Solomon, M.B. Keller, W.H. Coryell, Subthreshold hypomanic symptoms in progression from unipolar major depression to bipolar disorder, Am. J. Psychiatry 168 (2011) 40–48, https://doi.org/10.1176/appi.ajp.2010.10030328.

[58] A. Ratheesh, C. Davey, S. Hetrick, M. Alvarez-Jimenez, C. Voutier, A. Bechdolf, et al., A systematic review and meta-analysis of prospective transition from major depression to bipolar disorder, Acta Psychiatr. Scand. 135 (2017) 273–284, https://doi.org/10.1111/acps.12686.

[59] A.C. Tse, M.L. Fok, L.C. Yim, M.M. Leung, C.M. Leung, Diagnostic conversion to bipolar disorder in unipolar depressed patients in Hong Kong: a 20-year follow-up study, J. Affect. Disord. 286 (2021) 94–98, https://doi.org/10.1016/j.jad.2021.02.060.

[60] C. Dibner, U. Schibler, Circadian timing of metabolism in animal models and humans, J. Intern. Med. 277 (2015) 513–527, https://doi.org/10.1111/joim.12347.

[61] A.M. Rosenwasser, F.W. Turek, Neurobiology of circadian rhythm regulation, Sleep Med. Clin. 10 (2015) 403–412, https://doi.org/10.1016/j.jsmc.2015.08.003.

[62] M. Münch, A. Wirz-Justice, S.A. Brown, T. Kantermann, K. Martiny, O. Stefani, et al., The role of daylight for humans: gaps in current knowledge, Clocks Sleep 2 (2020) 61–85, https://doi.org/10.3390/clockssleep2010008.

[63] S.L. Chellappa, Individual differences in light sensitivity affect sleep and circadian rhythms, Sleep 44 (2021) zsaa214, https://doi.org/10.1093/sleep/zsaa214.
[64] J. Qian, F.A.J.L. Scheer, Circadian system and glucose metabolism: implications for physiology and disease, Trends Endocrinol. Metab. 27 (2016) 282–293, https://doi.org/10.1016/j.tem.2016.03.005.
[65] M.C. Melo, R.F. Garcia, V.B. Linhares Neto, M.B. Sá, L.M. de Mesquita, C.F. de Araújo, et al., Sleep and circadian alterations in people at risk for bipolar disorder: a systematic review, J. Psychiatr. Res. 83 (2016) 211–219, https://doi.org/10.1016/j.jpsychires.2016.09.005.
[66] P. Ritter, B. Soltmann, C. Sauer, A. Yakac, L. Boekstaegers, et al., Supersensitivity of patients with bipolar I disorder to light-induced phase delay by narrow bandwidth blue light, Biological Psychiatry Global Open Science 2 (2021) 28–35. https://www.sciencedirect.com/science/article/pii/S2667174321000501.
[67] G. Morris, M. Berk, The many roads to mitochondrial dysfunction in neuroimmune and neuropsychiatric disorders, BMC Med. 13 (2015) 68, https://doi.org/10.1186/s12916-015-0310-y.
[68] G. Morris, K. Walder, S.L. McGee, O.M. Dean, S.J. Tye, M. Maes, M. Berk, A model of the mitochondrial basis of bipolar disorder, Neurosci. Biobehav. Rev. 74 (Pt A) (2017) 1–20, https://doi.org/10.1016/j.neubiorev.2017.01.014.
[69] G.E. Hunt, G.S. Malhi, M. Cleary, H.M. Lai, T. Sitharthan, Prevalence of comorbid bipolar and substance use disorders in clinical settings, 1990-2015: systematic review and meta-analysis, J. Affect. Disord. 206 (2016) 331–349, https://doi.org/10.1016/j.jad.2016.07.011.
[70] G.E. Hunt, G.S. Malhi, M. Cleary, H.M. Lai, T. Sitharthan, Comorbidity of bipolar and substance use disorders in national surveys of general populations, 1990-2015: systematic review and meta-analysis, J. Affect. Disord. 206 (2016) 321–330, https://doi.org/10.1016/j.jad.2016.06.051.
[71] M. Meyrel, B. Rolland, P.A. Geoffroy, Alterations in circadian rhythms following alcohol use: a systematic review, Prog. Neuro-Psychopharmacol. Biol. Psychiatry 99 (2020), 109831, https://doi.org/10.1016/j.pnpbp.2019.109831.
[72] P.K. Parekh, A.R. Ozburn, C.A. McClung, Circadian clock genes: effects on dopamine, reward and addiction, Alcohol 49 (2015) 341–349, https://doi.org/10.1016/j.alcohol.2014.09.034.
[73] E.K. Tamura, K.S. Oliveira-Silva, F.A. Ferreira-Moraes, E.A.V. Marinho, N. N. Guerrero-Vargas, Circadian rhythms and substance use disorders: a bidirectional relationship, Pharmacol. Biochem. Behav. 201 (2021), 173105, https://doi.org/10.1016/j.pbb.2021.173105.
[74] M. Ventura-Cots, A.E. Watts, M. Cruz-Lemini, N.D. Shah, N. Ndugga, P. McCann, et al., Colder weather and fewer sunlight hours increase alcohol consumption and alcoholic cirrhosis worldwide, Hepatology 69 (2019) 1916–1930, https://doi.org/10.1002/hep.30315.
[75] M. Bauer, T. Glenn, M. Alda, O.A. Andreassen, E. Angelopoulos, R. Ardau, Y. Ayhan, et al., Association between solar insolation and a history of suicide attempts in bipolar I disorder, J. Psychiatr. Res. 113 (2019) 1–9, https://doi.org/10.1016/j.jpsychires.2019.03.001.
[76] M. Buoli, B.M. Cesana, B. Dell'Osso, A. Fagiolini, A. de Bartolomeis, E. Bondi, et al., Gender-related differences in patients with bipolar disorder: a nationwide study, CNS Spectr. 24 (2019) 589–596, https://doi.org/10.1017/S1092852918001529.
[77] L. Cremaschi, B. Dell'Osso, M. Vismara, C. Dobrea, M. Buoli, T.A. Ketter, A. C. Altamura, Onset polarity in bipolar disorder: a strong association between first depressive episode and suicide attempts, J. Affect. Disord. 209 (2017) 182–187, https://doi.org/10.1016/j.jad.2016.11.043.
[78] R.J. Baldessarini, G.L. Faedda, E. Offidani, G.H. Vázquez, C. Marangoni, G. Serra, et al., Antidepressant-associated mood-switching and transition from unipolar major depression to bipolar disorder: a review, J. Affect. Disord. 148 (2013) 129–135, https://doi.org/10.1016/j.jad.2012.10.033.
[79] L.V. Kessing, I. Willer, P.K. Andersen, J.D. Bukh, Rate and predictors of conversion from unipolar to bipolar disorder: a systematic review and meta-analysis, Bipolar Disord. 19 (2017) 324–335, https://doi.org/10.1111/bdi.12513.
[80] R.J. Baldessarini, G.H. Vázquez, L. Tondo, Bipolar depression: a major unsolved challenge, Int. J. Bipolar Disord. 8 (2020) 1, https://doi.org/10.1186/s40345-019-0160-1.
[81] M. Barbuti, L. Mazzarini, E. Vieta, J.M. Azorin, J. Angst, C.L. Bowden, et al., Relationships between recurrence and polarity in major depressive disorders: pooled analysis of the BRIDGE and BRIDGE-II-MIX cohorts, J. Affect. Disord. 256 (2019) 250–258, https://doi.org/10.1016/j.jad.2019.06.005.
[82] M.L. Phillips, D.J. Kupfer, Bipolar disorder diagnosis: challenges and future directions, Lancet 381 (2013) 1663–1671, https://doi.org/10.1016/S0140-6736(13)60989-7.
[83] K. Fritz, A.M.T. Russell, C. Allwang, S. Kuiper, L. Lampe, G.S. Malhi, Is a delay in the diagnosis of bipolar disorder inevitable? Bipolar Disord. 19 (2017) 396–400, https://doi.org/10.1111/bdi.12499.
[84] H. Shen, L. Zhang, C. Xu, J. Zhu, M. Chen, Y. Fang, Analysis of misdiagnosis of bipolar disorder in an outpatient setting, Shanghai Arch. Psychiatry 30 (2018) 93–101. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5936046/.
[85] M.D. Stensland, J.F. Schultz, J.R. Frytak, Depression diagnoses following the identification of bipolar disorder: costly incongruent diagnoses, BMC Psychiatry 10 (2010) 39, https://doi.org/10.1186/1471-244X-10-39.
[86] C. O'Donovan, M. Alda, Depression preceding diagnosis of bipolar disorder, Front Psychiatry 11 (2020) 500, https://doi.org/10.3389/fpsyt.2020.00500.
[87] J.S. Carpenter, J.J. Crouse, E.M. Scott, S.L. Naismith, C. Wilson, J. Scott, et al., Circadian depression: a mood disorder phenotype, Neurosci. Biobehav. Rev. 126 (2021) 79–101, https://doi.org/10.1016/j.neubiorev.2021.02.045.
[88] A. Murru, G. Guiso, M. Barbuti, G. Anmella, N. Verdolini, L. Samalin, et al., The implications of hypersomnia in the context of major depression: results from a large, international, observational study, Eur. Neuropsychopharmacol. 29 (2019) 471–481, https://doi.org/10.1016/j.euroneuro.2019.02.011.
[89] R. Gonzalez, S.D. Gonzalez, M.J. McCarthy, Using chronobiological phenotypes to address heterogeneity in bipolar disorder, Mol. Neuropsychiatry 5 (Suppl. 1) (2020) 72–84, https://doi.org/10.1159/000506636.
[90] M. Ridley, G. Rao, F. Schilbach, V. Patel, Poverty, depression, and anxiety: causal evidence and mechanisms, Science. 370 (2020) eaay0214, https://doi.org/10.1126/science.aay0214.
[91] P.S. Wang, S. Aguilar-Gaxiola, J. Alonso, M.C. Angermeyer, G. Borges, E. J. Bromet, et al., Use of mental health services for anxiety, mood, and substance disorders in 17 countries in the WHO world mental health surveys, Lancet 370 (2007) 841–850, https://doi.org/10.1016/S0140-6736(07)61414-7.
[92] WHO, Mental Health ATLAS 2017. https://www.who.int/publications/i/item/9789241514019, 2017 (accessed 12 March 2022).
[93] K. Guyot, R.V. Reeves, Unpredictable work hours and volatile incomes are long-term risks for American workers. Brookings. https://www.brookings.edu/blog/up-front/2020/08/18/unpredictable-work-hours-and-volatile-incomes-are-long-term-risks-for-american-workers/, 2020 (accessed 12 March 2022).
[94] M.R. Winkler, S. Mason, M.N. Laska, M.J. Christoph, D. Neumark-Sztainer, Does non-standard work mean non-standard health? Exploring links between non-standard work schedules, health behavior, and well-being, SSM Popul. Health. 4 (2017) 135–143, https://doi.org/10.1016/j.ssmph.2017.12.003.
[95] S.M. James, K.A. Honn, S. Gaddameedhi, H.P.A. Van Dongen, Shift work: disrupted circadian rhythms and sleep-implications for health and well-being, Curr. Sleep Med. Rep. 3 (2017) 104–112, https://doi.org/10.1007/s40675-017-0071-6.
[96] S.J. Lambert, P.J. Fugiel, J.R. Henly, Schedule unpredictability among early career workers in the US labor market: a national snapshot. Chicago, IL: Employment Instability, Family Well-being, and Social Policy Network, University of Chicago. https://crownschool.uchicago.edu/sites/default/files/uploads/lambert.fugiel.henly_.executive_summary.b_0.pdf, 2014 (accessed 12 March 2022).
[97] M. Bauer, T. Glenn, S. Monteith, J.F. Gottlieb, P.S. Ritter, J. Geddes, et al., The potential influence of LED lighting on mental illness, World J. Biol. Psychiatry 19 (2018) 59–73, https://doi.org/10.1080/15622975.2017.1417639.
[98] C. Cajochen, S. Frey, D. Anders, J. Späti, M. Bues, A. Pross, et al., Evening exposure to a light-emitting diodes (LED)-backlit computer screen affects circadian physiology and cognitive performance, J Appl Physiol 110 (2011) (1985) 1432–1438, https://doi.org/10.1152/japplphysiol.00165.2011.
[99] G. Tosini, I. Ferguson, K. Tsubota, Effects of blue light on the circadian system and eye physiology, Mol. Vis. 22 (2016) 61–72. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4734149/.
[100] Y. Touitou, S. Point, Effects and mechanisms of action of light-emitting diodes on the human retina and internal clock, Environ. Res. 190 (2020), 109942, https://doi.org/10.1016/j.envres.2020.109942.
[101] B. Carter, P. Rees, L. Hale, D. Bhattacharjee, M.S. Paradkar, Association between portable screen-based media device access or use and sleep outcomes: a systematic review and meta-analysis, JAMA Pediatr. 170 (2016) 1202–1208, https://doi.org/10.1001/jamapediatrics.2016.2341.
[102] M. Hysing, S. Pallesen, K.M. Stormark, R. Jakobsen, A.J. Lundervold, B. Sivertsen, Sleep and use of electronic devices in adolescence: results from a large population-based study, BMJ Open 5 (2015), e006748, https://doi.org/10.1136/bmjopen-2014-006748.
[103] D. Paksarian, K.E. Rudolph, E.K. Stapp, G.P. Dunster, J. He, D. Mennitt, et al., Association of outdoor artificial light at night with mental disorders and sleep patterns among US adolescents, JAMA Psychiatry 77 (2020) 1266–1275, https://doi.org/10.1001/jamapsychiatry.2020.1935.
[104] K.M. Zitting, M.Y. Münch, S.W. Cain, W. Wang, A. Wong, J.M. Ronda, et al., Young adults are more vulnerable to chronic sleep deficiency and recurrent circadian disruption than older adults, Sci. Rep. 8 (2018) 11052, https://doi.org/10.1038/s41598-018-29358-x.
[105] AMA (American Medical Association), Human and environmental effects of light emitting diode (LED) community lighting. Report of the council on science and public health. CSAPH Report 2-A-16. https://www.ama-assn.org/sites/ama-assn.org/files/corp/media-browser/public/about-ama/councils/Council%20Reports/council-on-science-public-health/a16-csaph2.pdf, 2016 (accessed 12 March 2022).
[106] R.G. Foster, S. Hughes, S.N. Peirson, Circadian photoentrainment in mice and humans, Biology (Basel) 9 (2020) 180, https://doi.org/10.3390/biology9070180.
[107] M.L. Aranda, T.M. Schmidt, Diversity of intrinsically photosensitive retinal ganglion cells: circuits and functions, Cell. Mol. Life Sci. 78 (2021) 889–907, https://doi.org/10.1007/s00018-020-03641-5.
[108] F. Rijo-Ferreira, J.S. Takahashi, Genomics of circadian rhythms in health and disease, Genome Med. 11 (2019) 82, https://doi.org/10.1186/s13073-019-0704-0.
[109] N. Goel, M. Basner, H. Rao, D.F. Dinges, Circadian rhythms, sleep deprivation, and human performance, Prog. Mol. Biol. Transl. Sci. 119 (2013) 155–190, https://doi.org/10.1016/B978-0-12-396971-2.00007-5.
[110] T. Roenneberg, T. Kuehnle, M. Juda, T. Kantermann, K. Allebrandt, M. Gordijn, et al., Epidemiology of the human circadian clock, Sleep Med. Rev. 11 (2007) 429–438, https://doi.org/10.1016/j.smrv.2007.07.005.
[111] A.J.K. Phillips, P. Vidafar, A.C. Burns, E.M. McGlashan, C. Anderson, S.M. W. Rajaratnam, et al., High sensitivity and interindividual variability in the

response of the human circadian system to evening light, Proc. Natl. Acad. Sci. U. S. A. 116 (2019) 12019–12024, https://doi.org/10.1073/pnas.1901824116.
[112] P.A. Geoffroy, F. Bellivie, J. Scott, B. Etain, Seasonality and bipolar disorder: a systematic review, from admission rates to seasonality of symptoms, J. Affect. Disord. 168 (2014) 210–223, https://doi.org/10.1016/j.jad.2014.07.002.
[113] G. Fico, M. de Toffol, G. Anmella, M. Sagué-Vilavella, A. Dellink, N. Verdolini, et al., Clinical correlates of seasonality in bipolar disorder: a specifier that needs specification? Acta Psychiatr. Scand. 143 (2021) 162–171, https://doi.org/10.1111/acps.13251.
[114] E.E. Haroz, M. Ritchey, J.K. Bass, B.A. Kohrt, J. Augustinavicius, L. Michalopoulos, et al., How is depression experienced around the world? A systematic review of qualitative literature, Soc. Sci. Med. 183 (2017) 151–162, https://doi.org/10.1016/j.socscimed.2016.12.030.
[115] L.J. Kirmayer, A. Gomez-Carrillo, S. Veissière, Culture and depression in global mental health: an ecosocial approach to the phenomenology of psychiatric disorders, Soc. Sci. Med. 183 (2017) 163–168, https://doi.org/10.1016/j.socscimed.2017.04.034.
[116] M. Kummu, O. Varis, The world by latitudes: a global analysis of human population, development level and environment across the north–south axis over the past half century, Appl. Geogr. 31 (2010) 495–507, https://doi.org/10.1016/j.apgeog.2010.10.009.
[117] F. Falchi, P. Cinzano, D. Duriscoe, C.C. Kyba, C.D. Elvidge, K. Baugh, et al., The new world atlas of artificial night sky brightness, Sci. Adv. 2 (2016), e1600377, https://doi.org/10.1126/sciadv.1600377.
[118] M. Bauer, T. Glenn, M. Alda, O.A. Andreassen, E. Angelopoulos, R. Ardau, et al., Influence of light exposure during early life on the age of onset of bipolar disorder, J. Psychiatr. Res. 64 (2015) 1–8, https://doi.org/10.1016/j.jpsychires.2015.03.013.
[119] C.M. Ciarleglio, J.C. Axley, B.R. Strauss, K.L. Gamble, D.G. McMahon, Perinatal photoperiod imprints the circadian clock, Nat. Neurosci. 14 (2011) 25–27, https://doi.org/10.1038/nn.2699.