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2020

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### Repository Citation

Amin, A. (2020). The Effects of Daily Sunlight Levels on Suicide Rates. Wright State University. Dayton, Ohio.

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# The Effects of Daily Sunlight Levels on Suicide Rates

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Scholarship in Medicine Final Report

## **Abstract**

The correlation between sunlight and mental health has been long studied and is even involved in the development of Seasonal Affective Disorder (SAD), with subsequent development of light therapy for affected individuals. This points towards the question of the effects of varying levels of daily sunlight in the United States on rates of suicide – a reflection of the extreme state of suboptimal mental health. I have ventured to study this question, using publicly available data on the daily sunlight levels in various states in the U.S. during each month of the year and the rates of suicide in those respective states and months. I analyzed and compared average daily sunlight for each month of the years 2001-2010 for each state to determine where each state and month was relative to the mean using descriptive statistics and Z-scores. Then, I analyzed the average suicide rates for those corresponding values to determine where each state and month was relative to the mean again using descriptive statistics and Z-scores. The sunlight and suicide rates data were then compared with each other using a stepwise linear regression to determine if there was a significant correlation. While there were no outlying sunlight levels or suicide rates for each state and month, it appeared that there were numerous states and months with sunlight levels and suicide rates in the same direction, rather than opposite, which contradicts the hypothesis. Upon linear regression analysis, it was found that there was no significant correlation between daily sunlight levels and suicide rates ( $P > 0.16$ ). These findings suggest that the link

between sunlight levels and suicide rates is likely multifactorial, and consideration of other contributing factors would be of benefit.

Key Words: sunlight, suicide, mental health, mental illness, states, months

### **Introduction/Literature Review**

The idea of the positively correlated association between happiness and sunlight exposure has been widely pondered upon in medicine and even goes on to support the basis of various disorders, including the often-referenced Seasonal Affective Disorder (SAD). SAD is a condition in which affected individuals have more of a depressive affect during fall and winter months. In fact, there has been found a significant correlation between winter months in northern latitudes and increased rates of SAD.<sup>1</sup> Though this was studied in bipolar patients, participants were found to have more symptomatic depressive episodes in the colder and darker months and latitudes. Studies in the workplace have shown that sunlight exposure is a direct predictor of anxiety and depression, and increased sunlight exposure has been correlated with increased job satisfaction.<sup>2</sup> This supported the rationale for workplaces improving their exposure to natural light. Further, therapies to target the issue of limited sun exposure in SAD have been developed in the form of light therapy and have been proven to have antidepressant effects.<sup>3</sup>

The above referenced studies would point towards the notion that decreased sunlight exposure would be associated with more mental health problems in the general population. It has even been established that smaller changes in sunlight exposure can contribute to SAD in climates without the traditional four seasons.<sup>4</sup> SAD was found to be prevalent in tropical latitudes, in which the summer and winter months do have different average daily sunlight levels, albeit not as drastic of a difference.<sup>4</sup> However, one study suggests that there are more factors contributing to mental health than just the perceived direct correlation of increased sunlight with

better mental health outcomes. In the last century, workplaces have increasingly shifted from being in an outdoor environment to an indoor environment, with the average working person now spending 90% of their time indoors.<sup>5</sup> With this, there appears to have been a shift in attitude regarding being outdoors as well, due to the argument that increased sunlight exposure can cause skin cancer, which produces a moderate level of anxiety in some during the summer months.<sup>5</sup> As such, while there still may be extensive links between increased sunlight exposure and better mental health outcomes, the true link may be multifactorial.

One way to measure the mental health of a population is to study the rates of suicide in that population. Some studies from the Southern Hemisphere have established the highest suicide rates in December and the lowest in June, corresponding to high and low levels of sunlight, respectively.<sup>6</sup> This is the opposite of what would be expected, considering that December is considered a summer month in the Southern Hemisphere. However, another study in the Northern Hemisphere has showed that in patients with Seasonal Affective Disorder, suicides were highest in the months August and September, when sunlight levels began to decline.<sup>7</sup> The evidence of variability between seasons in suicide rates in the general population of the Southern Hemisphere and in SAD patients of the Northern Hemisphere does not speak to whether there is significant variability in the general population of the Northern Hemisphere. This raises the question if there exists a significant variation of suicide rates in the general population in a Northern Hemisphere country. I have therefore analyzed the rates of suicide in various states and all months of the year in the U.S. and their respective average daily sunlight levels to determine if there is a correlation between sunlight and suicides.

### **Hypothesis/Specific Aims/Research Questions**

1. How much variation is there in average daily sunlight among different states in the U.S. from the years 2001-2010?
2. How much variation is there in average suicide rates of 25-34-year olds among different states in the U.S. from the years 2001-2010?
3. How much variation is there in average daily sunlight across each of the 12 months in the U.S. from the years 2001-2010?
4. How much variation is there in the average suicide rates of 25-34-year olds across each of the 12 months of the U.S. from the years 2001-2010?
5. How is amount of average daily sunlight correlated with suicide rates among 25-34-year olds for each state and each month from the years 2001-2010 in the United States?

## **Methods**

### *Context/Protocol*

Two sets of data were obtained from the United States during the years 2001-2010, including average daily sunlight levels for each state during each month of that time period, as well as suicide rates for men and women aged 25-34 for each state during each month of that time period. The states of Alaska and Hawaii were excluded from this initial data collection, and the District of Columbia was included as its own state.

The data on average daily sunlight levels was obtained from North American Land Data Assimilation System Daily Sunlight (NLDAS) ( $\text{KJ}/\text{m}^2$ ) through CDC Wonder's website. The data was requested from the dates January 1<sup>st</sup>, 2001 to December 31<sup>st</sup>, 2010 and grouped by state and month. The reported data on sunlight was measured by the NLDAS using 1/8-degree geographic-area (14x14 kilometer square) grids throughout the respective regions being measured.<sup>8</sup> The grids were recognized by the county of the state they covered, and data from the

grid covering the greatest county area was recorded to represent that county.<sup>8</sup> The daily sunlight from each county was reported in kilojoules per square meter (KJ/m<sup>2</sup>) as an average of all the measurements during the requested time intervals and regions.<sup>8</sup> For the purposes of this study, the data for each of the 12 months in each respective state was obtained as the average of each of the counties' data for each respective state over each month of the year, as reported by CDC Wonder. The data for each month was reported as the average of that month over the 10-year span, and hence, there were 12 values per state.

The data on suicide rates in the United States was obtained from the Centers for Disease Control and Prevention, National Center for Health Statistics through CDC Wonder's website. The data was requested for males and females aged 25-34 for the months between January 2001 and December 2010 in all contiguous states, and the cause of death was classified as "Suicide." The reported data was classified in this way by the World Health Organization's definition of suicide, being "the disease or injury which initiated the train of events leading directly to death, or the circumstances of the accident or violence which produced the fatal injury."<sup>9</sup> Based upon this definition, physicians reported the deaths from the included data as suicides on each of the death certificates, which were reviewed by the CDC, and subsequently reported for use.<sup>9</sup> The data was then organized based on the number of suicides in the requested age range per month per contiguous state in the requested time period. Of note, if the number of suicides was under 10, then it was not reported by CDC Wonder, and hence, not included in this study.

Further, to determine the rates of suicide, census data was also needed, which was obtained from the U.S. Census Bureau through CDC Wonder's website, using the same request form described above for suicides. The U.S. Census Bureau reported population estimates of U.S. national, state, and county resident populations on an annual basis.<sup>9</sup> For the purposes of this

study, the state level population estimates were used with the respective number of suicides to determine the suicide rates.

### *Data Collection*

As described above, the two sets of data were obtained by submitting two request forms on CDC's website. To obtain data on daily average sunlight levels for each month from the years 2001-2010 in each contiguous U.S. state, the form was located under "Environmental Health." The results were grouped by "State" and "Month," and all 48 contiguous states were included. The data was requested from the dates January 1<sup>st</sup>, 2001 to December 31<sup>st</sup>, 2010. This provided 12 values reported in  $\text{KJ/m}^2$  for each contiguous U.S. state and the District of Columbia, corresponding to the daily average sunlight levels for each month of the year (averaged over the 10 years being studied). The data was then duplicated to determine average daily sunlight levels for each state over the entire 10-year period, which yielded 49 values (one for each contiguous state, as well as the District of Columbia). This allowed for later analysis of variation in sunlight levels across states (RQ #1). The original data was then duplicated again to determine average daily sunlight levels for each month over the 10-year period for the entire U.S., which yielded 12 values (one for each month of the year). This allowed for later analysis of variation in sunlight levels across each month of the year (RQ #3).

To obtain data on suicides of individuals aged 25-34 for each month from the years 2001-2010 in each state, the form was located under "Underlying Causes of Death" on CDC Wonder's website. The results were grouped by "State" and "Month," and all 48 contiguous states were included. The data was requested for males and females aged 25-34 for the months between January 2001 and December 2010, and the cause of death was classified as "Suicide." The reported number of suicides for each state and month were divided by the state's population for

that respective year to then yield suicide rates for each state and month, reported as a percentage. One limitation of this data set is that while suicides were reported for each month of the given time period, the census was only taken annually. Therefore, the same population was used to determine suicide rates among various months of the same year.

Further, the data was condensed to report an average suicide rate for each month for each state, ideally yielding 12 suicide rates per state for each month of the year, to correspond with the values for average daily sunlight. However, because CDC Wonder did not report the number of suicides if they were under 10 for a particular state's month, there was missing data in the smaller states. Therefore, there were states that had no data for a given month in any of the years being studied, so there were less than 12 values for the suicide rates to account for each month. Some of these smaller states, as well the District of Columbia, were omitted from the data at this stage to ensure more consistent data for analysis later. These corresponding states were also removed from the data on sunlight to allow for appropriate comparison of the two variables later. This is justified because the remaining states still had sufficient variability in their sunlight levels to account for both the high and low ends of the spectrum.

This data was then duplicated to determine average suicide rates for each state over the entire 10-year period, which yielded 30 values (one for each of the remaining states being studied). This allowed for later analysis of variation in suicide rates across states (RQ #2). The data was then duplicated again to determine average suicide rates for each month over the 10-year period for the entire U.S., which yielded 12 values (one for each month of the year). This allowed for later analysis of variation in suicide rates across each month of the year (RQ #4).

The two datasets for average daily sunlight levels and suicide rates were then combined and lined up appropriately, each with a value for their average for each month of each remaining

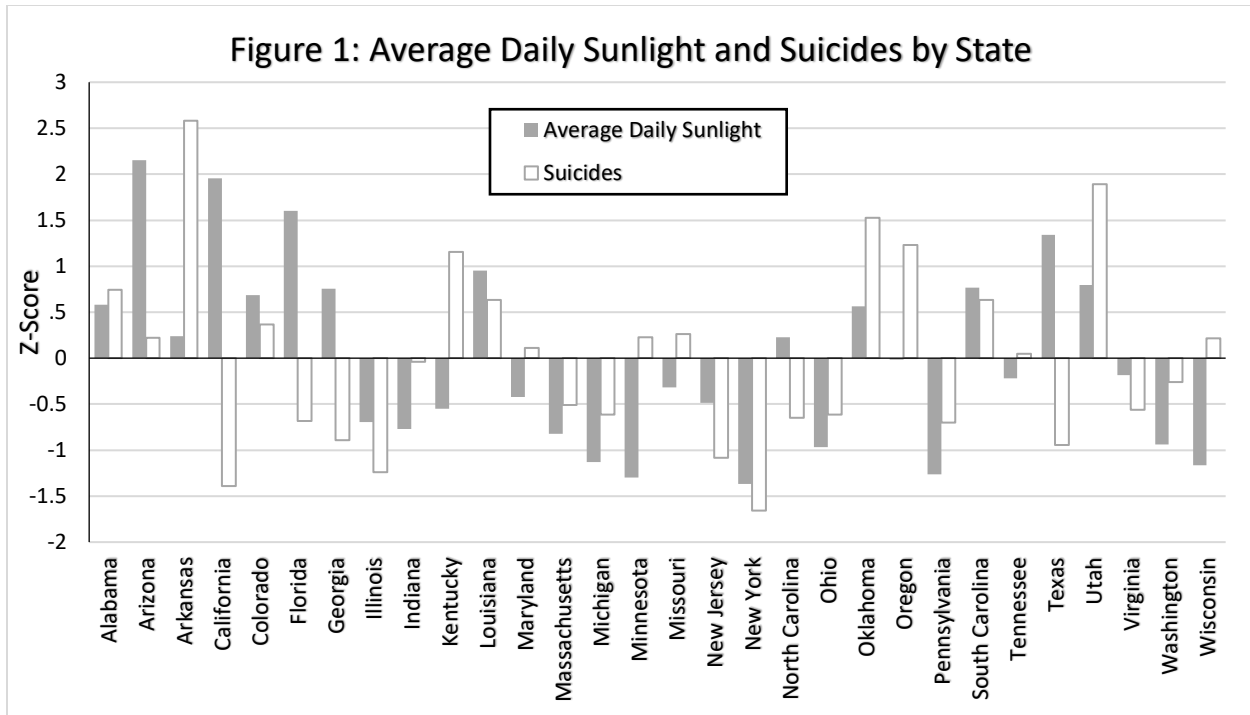


state. Of note, there were some remaining states in the study that did not have sufficient data to yield 12 suicide rates to represent each month, but these states were still represented due to having enough valuable data to include, given they were only missing 1-2 months' data. For these months, the respective average daily sunlight levels were also omitted from the data. The end data used in this study was from the states Alabama, Arizona, Arkansas, California, Colorado, Florida, Georgia, Illinois, Indiana, Kentucky, Louisiana, Maryland, Massachusetts, Michigan, Minnesota, Missouri, New Jersey, New York, North Carolina, Ohio, Oklahoma, Oregon, Pennsylvania, South Carolina, Tennessee, Texas, Utah, Virginia, Washington, and Wisconsin.

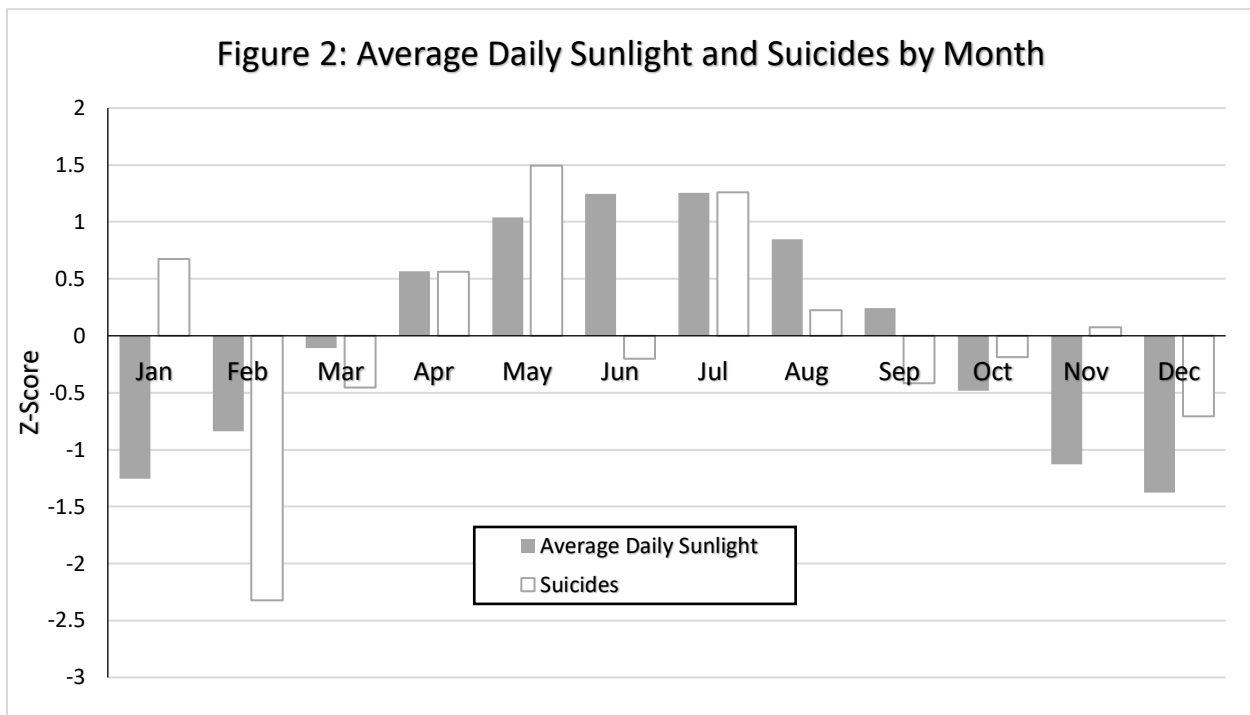
### *Data Analysis*

To analyze the variability of daily average sunlight levels and suicide rates across different states and different months, descriptive statistics were obtained for each of the four duplicated data sets described above to obtain Z-scores for each piece of data in question. Z-scores were obtained for average daily sunlight levels for each of the 30 states over the entire 10-year period (RQ #1), average daily sunlight levels across each month of the year (RQ #3), suicide rates for each of the 30 states over the entire 10-year period (RQ #2), and suicide rates across each month of the year (RQ #4). Further, to determine if there is a significant correlation between average daily sunlight levels and suicide rates, a stepwise linear regression was performed on the final combined dataset including the sunlight levels and suicide rates (RQ #5). Suicide rates were used as the dependent variable.

### **Results**



**Fig. 1.** Average daily sunlight levels and suicides (2001-2010) for various states (n = 30) compared to the mean levels. All states were within 3 standard deviations of the mean and no states were outliers for both sunlight levels and suicides.



**Fig. 2.** Average daily sunlight levels and suicides (2001-2010) for each month (n = 12) compared to the mean levels. All months were within 3 standard deviations of the mean and no months were outliers for both sunlight levels and suicides.

From 2001 to 2010, daily sunlight levels from various states ( $n = 30$ ) for each month of the year ( $n = 12$ ) were compared with the corresponding suicide rates in individuals aged 25-34 ( $N = 342$ ). Looking at the aggregate data from each state ( $n = 30$ ), all reported sunlight levels and suicide rates were within 3 standard deviations and no outliers were found. The state of Arizona had over 2 standard deviations greater sunlight than the mean, which is increased but within normal limits ( $CI = 95\%$ ) (Figure 1). Arizona's corresponding suicide rates were close to the mean and did not indicate decreased suicide rates (Figure 1). The state of Arkansas had approximately 2.5 standard deviations greater suicide rates than the mean, which was increased in comparison to the other states but within normal limits ( $CI = 95\%$ ) (Figure 1). Arkansas' corresponding sunlight levels were close to the mean and did not indicate increased sunlight levels (Figure 1). The rest of the aggregate data for states was within 2 standard deviations from the mean. The states California, Florida, Georgia, Kentucky, Maryland, Michigan, Missouri, North Carolina, Tennessee, Texas, and Wisconsin had opposite sign Z-scores for sunlight levels and suicide rates (one was positive, while the other was negative). The rest of the studied states had the same sign for Z-scores for their sunlight levels and suicide rates (both were either positive or negative).

Looking at the aggregate data from each month of the year ( $n = 12$ ), all reported sunlight levels and suicide rates were within 3 standard deviations and no outliers were found. The month of February had approximately 2 standard deviations less suicides than the mean, which is decreased in comparison than the rest of the months but within normal limits ( $CI = 95\%$ ) (Figure 2). February's corresponding sunlight levels were just under 1 standard deviation below the mean and did not indicate increased sunlight levels (Figure 2). The rest of the aggregate data for months was within 2 standard deviations from the mean. The months January, June, September,

and November had opposite sign  $Z$ -scores for sunlight levels and suicide rates (one was positive, while the other was negative). The rest of the months had the same sign for  $Z$ -scores for their sunlight levels and suicide rates (both were either positive or negative).

When looking at all of the data ( $N = 342$ ), linear regression of sunlight levels and suicide rates revealed a Pearson correlation of 0.076 and sig. 1-tailed correlation of 0.081 between the two variables, indicating a very weak correlation between sunlight levels and suicide.  $R^2$  value was reported to be 0.006. The effect of daily sunlight levels on suicide rates was insignificant ( $P = 0.16$ ) and no significant effect of daily sunlight levels on suicide rates could be observed.

## **Discussion**

Upon analysis of the effect of daily sunlight levels on suicide rates, the negligible correlation supports the notion that the incidence of suicides in states is truly multifactorial and any seasonal variation in suicide rates has more variables involved than just sunlight. Figure 1 shows that for a given deviance in daily sunlight levels for each state, there are nearly no states with corresponding magnitudes of suicide rates, whether in the same direction or the opposite direction. This supports the notion that variance in suicide rates across states may be impacted by sunlight that state receives, but there are likely other factors that are also influencing suicide rates, potentially including lifestyle and opportunities within that particular state as compared to other states.

Figure 2 shows that for the increase in daily sunlight levels for warmer months, including April, May, and July, there appeared to be proportional increases in suicide rates. This contradicts the hypothesis that the increased daily sunlight levels should correspond with decreased suicide rates, further supporting the notion that variance in suicide rates throughout the year is multifactorial, potentially including factors like seasonal allergies or anxiety of

developing skin cancer during the spring/summer months.<sup>5</sup> This finding may support a study in the Southern Hemisphere, whose summer and winter months are reversed, in which the summer months with increased sunlight tended to have higher suicide rates.<sup>6</sup> It should be noted that while the data in this study was able to draw a statistically significant correlation, our study was not and is merely speculating on trends.

The exceptionally weak correlation (Pearson correlation = 0.076, P = 0.16) between daily sunlight levels on suicide rates, using the full data (N = 342), posits that there may not even be a link between daily sunlight levels and suicide rates. Though it has been proven that increased sunlight levels have a direct correlation with decreased mental health issues, this data would suggest that mental health issues significantly affected by daily sunlight levels do not result in suicides of increased frequency.<sup>2</sup> Therefore, it is worthwhile to shift focus to the seasonal variations in mental health outcomes when applying practical solutions to public health. In addition, it is worthwhile to focus on variations between states and the measures they have taken on to affect mental health outcomes. For example, Florida and California had similar daily sunlight levels and similar low suicide rates, whereas Arizona also had similar daily sunlight levels but slightly increased suicide rates (Figure 1). Therefore, it would be worthwhile to focus on what Florida and California are doing for their residents that Arizona is not, or if there are increased stressors upon residents of Arizona that are not present for residents of Florida and California.

Lastly, though this study did not prove a significant correlation between sunlight and suicide rates, this does not rule out the importance of exposure to sunlight. Due to the prevalence of conditions like Seasonal Affective Disorder, exposure to sufficient sunlight on a daily basis is beneficial and likely to improve mental health and overall satisfaction with life.<sup>2-4</sup>

**Limitations**

While the results of this study were not able to draw a significant correlation between daily sunlight, there were some limitations in the complete analysis of data. Though 30 states were included in this study ( $n = 30$ ), the sample size could have been increased to 49 (48 contiguous US states and the District of Columbia). However, CDC Wonder did not report data for number of suicides if it was under 10, so there was not enough data for worthwhile analysis of the smaller states, so 19 states had to be omitted, effectively decreasing the sample size. In addition, of the 30 states studied, there were certain months during the 10 years that had less than 10 suicides and therefore were not reported, and average numbers of suicides for each particular month were used to represent the 10-year period.

**Conclusion**

With the results that were extracted from this study, future direction could involve studying the most effective measures that individual states are taking to improve their suicide rates in comparison to other states. In addition, the posited trend of increased suicides during summer months could be further delved into, namely involving the specific mental health diagnoses behind those statistics. While it does not appear that the incidence of Seasonal Affective Disorder corresponds with the same incidence of suicides throughout the year, knowledge of the emergence of other mental health diagnoses or stressors that do correspond with increased suicide rates would be of great value to the general public.

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