Title: Exploratory assessment of the relationship between environmental temperature and mental health

Author: Sehaj Gill, Junior, Notre Dame Preparatory Academy, Pontiac MI USA

Abstract

Environmental temperatures have been consistently increasing over the past several decades. The National Oceanic and Atmospheric Administration has reported that Earth's temperature has risen by an average of 0.14° Fahrenheit (0.08° Celsius) per decade since 1880, or about 2° F in total. The rate of warming since 1981 is more than twice as fast. During this period rate of temperature increase was 0.32° F (0.18° C) per decade (Lindsey & Dahlman, 2023). A warming climate has direct environmental implications that result in increased frequency and magnitude of extreme weather events that include heatwaves, droughts, flooding, winter storms, hurricanes, and wildfires (United Nations Environment Programme, 2023). Existing research has also uncovered that warmer climate is also associated with poor social, ecological, health, and economic outcomes (Barrage, 2020; Beine & Jeusette, 2018; Kaczan & Orgill-Meyer, 2019; Kolstad & Moore, 2019; Rocque et al., 2021). The present exploratory assessment contributes to a growing body of research associated with impacts of warmer environmental temperature and mental health. Publicly available data associated with average temperature and average number of mentally unhealthy days by county in the 48 contiguous U.S. states was collected for the years 2021, 2022 and 2023. Statistical tests were applied to these data. It was found that higher temperatures are associated with higher number of mentally unhealthy days at a 95.0% confidence level. This exploratory assessment provides basis for more granular and comprehensive analyses in the future.

Table of Contents

Introduction

Over the past decade, heat related weather records across the U.S. are being shattered (Perez, 2023). In fact, the National Aeronautics and Space Administration found that the summer of 2023 was Earth's hottest since global records began in 1880 (Biferno et al., 2023; Livingston, 2023). On July 6th, 2023, the world experienced it hottest day ever with an average global temperature of 62.74˚F or 17.08˚C (Paddison, 2023). This high point is part of a continuing trend that has been observed over the last several years (Levy & Przyborski, 2021). Several research studies have firmly established that global temperatures have been steady increasing (Levy & Przyborski, 2021; Sobrino et al., 2020; Rounce et al., 2023). "The global average surface temperature has significantly increased during the twentieth and early twenty-first century, with temperatures 1.09˚C [0.95–1.20˚C] higher in 2011–2020 compared to the preindustrial period (1850–1900), and with each of the last four decades successively warmer than all previous decades" (Gorodetskaya et al., 2023).

The ill-effects of the changing climate are of broad scope and far reaching. The changing climate has resulted in poor social, environmental, ecological, health and economic outcomes (Barrage, 2020; Beine & Jeusette, 2018; Kaczan & Orgill-Meyer, 2019; Kolstad & Moore, 2019; Rocque et al., 2021). Mullins & White (2019) found that "… higher temperatures increase emergency department visits for mental illness, suicides, and self-reported days of poor mental health". Further, higher thermal conditions have been found to result in cognitive deficits (Cedeño Laurent et al., 2018). Li et al. (2020) reported that cooler days reduce the probability of self-reporting days of bad mental health while hotter days increase this probability. Similarly, it was found that exposure to high temperatures leads to worse mental health (Hou et al., 2023). However, additional studies are needed to generalize the relationship between environmental

temperature and mental health and to enrich the growing body of research (Liu et al., 2021; Cameron et al., 2021; Liu et al., 2023).

Research Question and Hypothesis

This study aims to contribute to the body of research by performing an exploratory assessment of the relationship between environmental temperature and mental health. Specifically, the study assesses the relationship between publicly available average temperatures in the month of July for the years 2021, 2022 and 2023 for every county in the contiguous 48 states in the U.S. and average number of days impacted by poor mental health for the residents of same counties and in the same years.

Means and variances of the average Mentally Unhealthy Days were tested to ascertain whether the belong to independent groups. In other words, the statistical assessment involved testing whether different quartiles of Average Environment Temperature were associated with Mentally Unhealthy Days experienced by residents of counties in the 48 contiguous states in the U.S. between 2021 and 2023. Hence the hypotheses tested were:

- H0: $\mu 1 = \mu 2 = \mu 3$ and H1: Means are not all equal

The null and alternate hypotheses were tested using analysis of variance (ANOVA). Data were normalized, as needed. Target confidence level was 95.0% or higher ($p \leq 0.05$).

Data Collection

Publicly available county level Mentally Unhealthy Days data were collected for years 2021, 2022 and 2023 from University of Wisconsin Population Health Institute. Average July temperature data were downloaded from National Oceanic and Atmospheric Administration's (NOAA) National Center for Environmental Information for the same years. NOAA's data were limited to counties of the 48 contiguous states of the U.S. Hence, the counties from Alaska and

Hawaii were not included in the assessment. Federal Information Processing System (FIPS) codes were used to ensure data integrity and to correctly match the datasets from both sources.

Results

One-variable analyses were performed for the Mentally Unhealthy Days and Average Temperature datasets. It was found that the standard skewness for Average Temperature is outside the range of - 2 to +2. This indicated significant departures from normality. In order to address the non-normality due to negative skewness a power transformation was applied (van den Berg, 2021). Based on Box and Cox method (1964) the power transformation shown in equation 1 was selected to achieve minimum mean squared error.

$$1 + (AverageTemperature^{1.555} - 1)/(17.2353) \quad (1)$$

One variable analysis was repeated for the transformed normalized values. The results are included in table 1.

Table 1

Descriptive analysis

Attribute	**Mentally Unhealthy Days**	**Average Temperature**	**Normalized Temperature**
Count	9318		
Average	4.79	76.48	50.33
Standard deviation	0.67	5.76	5.76
Minimum	0	54.5	30.03
Maximum	7.50	97.5	72.8
Range	7.50	43	42.77
Stnd. skewness	0.18	-4.93	-0.16

Stnd. kurtosis	1.67	-1.17	-1.97

Pearson product moment between Mentally Unhealthy Days and Normalized Temperature was statistically significant and was calculated to be 0.26 with a p value of < 0.0001. The correlation coefficients range between -1 and +1 and measure the strength of the linear relationship between the variables. In this case, it must be noted that the strength of the relation can be deemed moderate at a statistically significant level.

To further explore the association between Mentally Unhealthy Days and Average Temperatures, analysis of variance test was performed. To complete this analysis, the Average Temperatures were grouped into 3 groups vis-à-vis 25^{th}, 50^{th} and 75^{th} percentile i.e., first, second and third quartile respectively. The results are shown in table 2. The ANOVA table decomposes the variance of Mentally Unhealthy Days into two components: a between-group component and a within-group component. The F-ratio, which in this case equals 387.59, is a ratio of the between-group estimate to the within-group estimate. Since the P-value of the F-test is less than 0.05, there is a statistically significant difference between the mean Mentally Unhealthy Days from one level of Temp Quartile to another at the 95.0% confidence level. Hence, the null hypothesis can be rejected.

Table 2

ANOVA Table for Mentally Unhealthy Days by Temp Quartile

Source	**Sum of Squares**	**Degrees of Freedom**	**Mean Square**	**F-Ratio**	**P-Value**
Between groups	318.70	2	159.35	387.59	< 0.0001
Within groups	3,829.62	9315	0.41		
Total (Corr.)	4,148.32	9317			

Further, to understand difference between each group multiple range tests were performed. The counts and means for each group along with values of 25th, 50th and 75th percentile are presented in table 3. The results of these tests are shown in Table 4. Fisher's least significant difference (LSD) procedure was used to discriminate among the means. The results seem to suggest that at a statistically significant level high Average Temperatures are associated with higher Mentally Unhealthy Days.

Table 3

Mentally Unhealthy Days Counts and Means by Temp Quartiles

Temp Quartile (value)	**Count**	**Mean**
Q1 (72.5°F/22.5°C)	2333	4.56
Q2(76.6°F/24.8°C)	4586	4.77
Q3 (80.6°F/27°C)	2399	5.07

Table 4

Multiple Range Tests for Mentally Unhealthy Days by Temp Quartile

Contrast	**Significance**	**Difference in Means**
Q1 – Q2	*	-0.21
Q1- Q3	*	-0.51
Q2 – Q3	*	-0.30

* denotes a statistically significant difference at the 95.0% confidence level

Finally, additional insight about the relationship was gleaned by constructing a cross tabulation between Temp Quartile and rounded Mentally Unhealthy Days. Chi-Sqaure test was performed to test for independence between the two variables. The P-value of the Chi-Square test was calculated to be < 0.0001. Hence, the rows and columns on the cross tabulation are not

independent at the 95.0% confidence level. In other words, the observed value of Temp Quartile for a particular case is related to its value for Mentally Unhealthy Days (rounded).

The results of the cross tabulation are shown in table 5 and figure 1. This table shows how often the 3 values of Temp Quartile occur together with each of the 6 values of Mentally Unhealthy Days (rounded). The first number in each cell of the table is the frequency. The second number shows the percentage of the entire table represented by that cell.

The cross tabulation shows that within the Q1 and Q2 groupings majority of the Mentally Unhealthy Days were in the 4-to-5-day range. However, Q2 had many more instances with 5 days. In the case of Q3 most instances were concentrated at 5 days. This would explain the difference in the means for these 3 groupings.

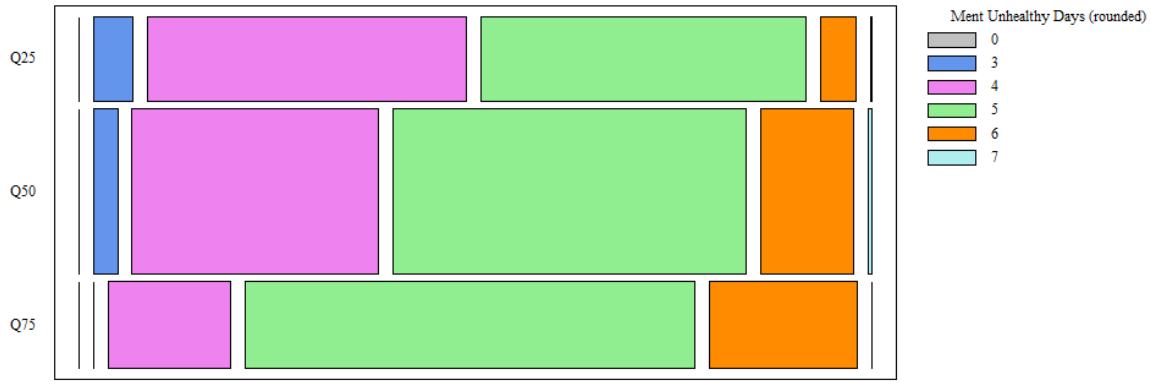
Table 5

Frequency Table for Temp Quartile by Mentally Unhealthy Days (rounded)

Days / Temp	**0**	**3**	**4**	**5**	**6**	**7**	Row Total
Q1	0 0.00%	129 1.38%	1030 11.05%	1052 11.29%	116 1.24%	6 0.06%	2333 25.04%
Q2	0 0.00%	156 1.67%	1565 16.80%	2248 24.13%	591 6.34%	26 0.28%	4586 49.22%
Q3	1 0.01%	2 0.02%	405 4.35%	1498 16.08%	492 5.28%	1 0.01%	2399 25.75%
Column Total	1 0.01%	287 3.08%	3000 32.20%	4798 51.49%	1199 12.87%	33 0.35%	9318 100.00%

Figure 1

Mosaic Chart for Temp Quartile by Mentally Unhealthy Days (rounded)



Conclusions

The analysis shows that warmer temperatures are associated with higher number of mentally unhealthy days. It was found that temperatures equal or lower to than 72.5°F /22.5°C were associated with an average of 4.56 mentally unhealthy days. Further, temperatures equal or higher than 80.6°F/27°C were associated with an average of 5.07 mentally unhealthy days. This is consistent with findings from other studies. Hence, it can be concluded that this exploratory assessment provides basis of further research that correlates the two factors at much more granular level. Additionally, further research can build upon the research included in the introduction section to establish causal relationships between the specific factors included in the present study.

References

Barrage, L. (2020). The fiscal costs of Climate Change. *AEA Papers and Proceedings*, *110*, 107–112. https://doi.org/10.1257/pandp.20201082

Beine, M. A., & Jeusette, L. (2018). A meta-analysis of the literature on climate change and migration. *SSRN Electronic Journal*. https://doi.org/10.2139/ssrn.3338771

Biferno, A., Shaftel, H., Callery, S., Jackson, R., Bailey, D., & Callery, S. (2023, November 30). *Global temperature - climate change*. Vital signs of the planet. https://climate.nasa.gov/vital-signs/global-temperature/

Box, G. E., & Cox, D. R. (1964). An analysis of transformations. *Journal of the Royal Statistical Society Series B: Statistical Methodology*, *26*(2), 211-243.

Cameron, L., Casson, N., Mauro, I., Friesen-Hughes, K., & Rocque, R. (2021). *Knowledge and Perceptions of the Health Impacts of Climate Change among Canadians*. https://doi.org/10.21203/rs.3.rs-1064960/v1

Cedeño Laurent, J. G., Williams, A., Oulhote, Y., Zanobetti, A., Allen, J. G., & Spengler, J. D. (2018). Reduced cognitive function during a heat wave among residents of non-air-conditioned buildings: An observational study of young adults in the summer of 2016. *PLOS Medicine*, *15*(7). https://doi.org/10.1371/journal.pmed.1002605

Gorodetskaya, I. V., Durán-Alarcón, C., González-Herrero, S., Clem, K. R., Zou, X., Rowe, P., Rodriguez Imazio, P., Campos, D., Leroy-Dos Santos, C., Dutrievoz, N., Wille, J. D., Chyhareva, A., Favier, V., Blanchet, J., Pohl, B., Cordero, R. R., Park, S.-J., Colwell, S.,

Lazzara, M. A., … Picard, G. (2023). Record-high Antarctic Peninsula temperatures and surface melt in February 2022: A compound event with an intense Atmospheric River. *Npj Climate and Atmospheric Science*, *6*(1). https://doi.org/10.1038/s41612-023-00529-6

Lindsey, R., & Dahlman, L. (2023, January 18). *Climate change: Global temperature*. NOAA Climate.gov. https://www.climate.gov/news-features/understanding-climate/climate-change-global-temperature

Kaczan, D. J., & Orgill-Meyer, J. (2019). The impact of climate change on migration: A synthesis of recent empirical insights. *Climatic Change*, *158*(3–4), 281–300. https://doi.org/10.1007/s10584-019-02560-0

Kolstad, C., & Moore, F. (2019). *Estimating the Economic Impacts of Climate Change Using Weather Observations*. https://doi.org/10.3386/w25537

Levy, R., & Przyborski, P. (2021). *Annual global temperature records*. The Earth Observatory. https://earthobservatory.nasa.gov/images/event/85098/annual-global-temperature-records

Li, Mengyao, Ferreira, S., & Smith, T. A. (2020). Temperature and self-reported mental health in the United States. *PLOS ONE*, *15*(3). https://doi.org/10.1371/journal.pone.0230316

Liu, J., Varghese, B. M., Hansen, A., Xiang, J., Zhang, Y., Dear, K., Gourley, M., Driscoll, T., Morgan, G., Capon, A., & Bi, P. (2021). Is there an association between hot weather and poor mental health outcomes? A systematic review and meta-analysis. *Environment International*, *153*, 106533. https://doi.org/10.1016/j.envint.2021.106533

Liu, X., He, J., Xiong, K., Liu, S., & He, B.-J. (2023). Identification of factors affecting public willingness to pay for heat mitigation and adaptation: Evidence from Guangzhou, China. *Urban Climate*, *48*, 101405. https://doi.org/10.1016/j.uclim.2022.101405

Livingston, I. (2023, December 29). *Extreme heat far outpaced cold in U.S. during record-warm 2023*. Weather . https://www.washingtonpost.com/weather/2023/12/29/record-heat-united-states-climate/

Mullins, J., & White, C. (2019). Temperature and mental health: Evidence from the spectrum of mental health outcomes. *SSRN Electronic Journal*. https://doi.org/10.2139/ssrn.3457647

NOAA National Centers for Environmental information. (2023, December). *County mapping*. Climate at a Glance. https://www.ncei.noaa.gov/access/monitoring/climate-at-a-glance/county/mapping

Paddison, L. (2023, July 27). *This month is the planet's hottest on record by far -- and hottest in around 120,000 years, scientists say*. CNN. https://www.cnn.com/2023/07/27/world/july-hottest-month-record-climate/index.html

Perez, K. (2023, July 18). *The US heat wave is smashing high-temperature records across the country, here are a few*. USA Today. https://www.usatoday.com/story/news/weather/2023/07/18/us-temperature-records-summer-heat-wave/70425231007/

Rocque, R. J., Beaudoin, C., Ndjaboue, R., Cameron, L., Poirier-Bergeron, L., Poulin-Rheault, R.-A., Fallon, C., Tricco, A. C., & Witteman, H. O. (2021). Health effects of climate

change: An overview of Systematic Reviews. *BMJ Open*, *11*(6). https://doi.org/10.1136/bmjopen-2020-046333

Rounce, D. R., Hock, R., Maussion, F., Hugonnet, R., Kochtitzky, W., Huss, M., Berthier, E., Brinkerhoff, D., Compagno, L., Copland, L., Farinotti, D., Menounos, B., & McNabb, R. W. (2023). Global Glacier Change in the 21st century: Every increase in temperature matters. *Science*, *379*(6627), 78–83. https://doi.org/10.1126/science.abo1324

Sobrino, J. A., Julien, Y., & García-Monteiro, S. (2020). Surface temperature of the planet Earth from Satellite Data. *Remote Sensing*, *12*(2), 218. https://doi.org/10.3390/rs12020218

United Nations Environment Programme. (2023). *Facts about the climate emergency*. UNEP. https://www.unep.org/facts-about-climate-emergency

University of Wisconsin Population Health Institute. (2023). *Explore health rankings*. County Health Rankings & Roadmaps. https://www.countyhealthrankings.org/explore-health-rankings

van den Berg, R. G. (2021). *Normalizing variable transformations – 6 simple options*. SPSS tutorials Normalizing Variable Transformations 6 Simple Options Comments. https://www.spss-tutorials.com/normalizing-variable-transformations