Dose-Response, 13:1, 2015
Formerly Nonlinearity in Biology, Toxicology, and Medicine

ISSN: 1559-3258
DOI: 10.2203/dose-response.14-024.Hart

International Dose-Response Society
www.Dose-Response.org

ASSOCIATION BETWEEN AIR TEMPERATURE AND CANCER DEATH RATES IN FLORIDA: AN ECOLOGICAL STUDY

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□ Proponents of global warming predict adverse events due to a slight warming of the planet in the last 100 years. This ecological study tests one of the possible arguments that might support the global warming theory – that it may increase cancer death rates. Thus, average daily air temperature is compared to cancer death rates at the county level in a U.S. state, while controlling for variables of smoking, race, and land elevation. The study revealed that lower cancer death rates were associated with warmer temperatures. Further study is indicated to verify these findings.

Keywords: Global warming, cancer, death rates, Florida

INTRODUCTION

Concern about the Earth warming up slightly in the last 100 years has been a hot topic in recent years. The concern pertains to a 1 degree Fahrenheit increase in a so-called global temperature (U.S. Environmental Protection Agency, undated) and dire consequences are predicted (Walsh, 2014). One prediction, based on a computer model, states that carbon-dioxide emissions and global warming could result in up to 20,000 worldwide "air-pollution-related deaths per year per degree Celsius" (Bergeron, 2008).

Existing literature tends to study possible health effects of temperature by looking at temperature characteristics such as its *variability* (Zanobettia *et al*, 2012) or heat *waves* (Haines *et al*, 2006). The present study compares: a) the relatively simple heat index of *average daily temperature* to b) the health outcome of cancer death rates at the county level in a U.S. state, using an ecological (population-based) design. No previous studies were found that did this.

Previous research has shown that higher land elevations have a beneficial association with cancer deaths (Jagger, 1998; Hart, 2011; Hart, 2014). The theory is that increase level of low level cosmic radiation that accompanies increased land elevation triggers a beneficial adaptive response, and is sometimes referred to as *radiation hormesis* (Luckey, 2006). Furthermore, land elevation and temperature may be correlated (higher land elevations correlated with cooler temperatures). Consequently, a rel-

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atively flat state was sought to avoid a possible interaction between these two environmental factors (land elevation and temperature).

The state selected for the present study was Florida due to its relatively flat elevation throughout the state. Specifically, Florida's highest land elevation point is 345 feet above seal level - Britton Hill, located in the northern part of the state - while its lowest point is sea level (zero feet), a difference of 345 feet (U.S., 2011). This is the smallest difference (between highest and lowest land elevation points) among all 50 states and District of Columbia. (U.S. Census Bureau, 2011). The region having the second smallest difference is District of Columbia (having a difference of 409 feet), followed by Delaware's difference of 448, and then Louisiana's difference of 543 feet and so on (U.S., 2011). Warnings for Florida include predictions of "health impacts and mortalities due to high temperatures…" (Borisova *et al*, 2008)

The primary purpose of the study was to compare cancer death rates to air temperature (the main predictor of interest in the study), while controlling for smoking rates, land elevation, and race.

METHODS

The *response* (outcome) variable in the study was mean age-adjusted cancer death rates (per 100,000) during 2006-2010 by Florida county, all ages, all cancer sites (National Cancer Institute, 2014a). Since death rates tend to differ by race and gender, and since different races may be represented in greater percentages in different parts of a state (that also have different temperatures), two populations were studied; one that was narrowly defined - white females, and the other that was broadly defined – all races, both genders. For the narrowly-defined population, the white race was selected because it provided the greatest number of counties that reported data for the cancer death rates. The female gender was selected based on the axiom, *ladies before gentlemen*. For the all races, both genders group, percent of whites including Hispanics, blacks including Hispanics, and Hispanic persons (National Cancer Institute, 2014b) were included to test their association with the death rates in this group (that is, to test whether a higher concentration of a race influenced the all-races death rates).

The *dose* (predictor) variables for both groups (white females; and all races, both genders) were:

a) Average daily air temperature (in Fahrenheit) for 2006-2010 by Florida county (Centers for Disease Control and Prevention, 2014), calculated by averaging the mean daily maximum and minimum temperatures. The resulting average is now referred to as "temperature." As an example of how this temperature was calculated, Alachua county's average daily maximum temperature for 2006-2010 was 79.9 degrees while its average daily minimum temperature was 59.7. The average of these two averages was 69.80, which was the temperature value used for this county. Temperatures were analyzed as a continuous variable (in regression) and categorical (quartiles, calculated in Excel 2003 [Microsoft Corp., Redmond, WA] for online mapping software (Diymaps, 2014). The same temperature variable was used for both race groups.

b) Since land elevation was a deciding factor in the selection of the state, it was included for analysis in the study. County elevation, from The National Map viewer and the U.S. Geological Survey for each Florida county (U.S. Geological Survey, 2014). The elevation was obtained from a drop down menu, "Get Elevation" and is the elevation at the geographic center for each county. The highest point using this method was 225.7 feet which of course is different than the aforementioned 345 feet mentioned as Florida's highest point. The reason for this discrepancy is that the former method is a measurement at the center of a county, which is not necessarily the highest point of any county. Indeed the highest point in Florida, Britton Hill, is on a border (of Florida and Alabama). The same land elevation variable was used for both race groups.

c) Since smoking is a cancer-related factor, it was included in the study. For white females, percent of adult white females who smoked in 2007 by Florida county were obtained (Florida Behavioral Risk Surveillance System, 2007). For all races, both genders, percent of all adults who smoked in 2007 by Florida county was also obtained (Florida Behavioral Risk Surveillance System, 2007).

d) An economic variable was included as a predictor since financial status may be a factor in death rates. The economic variable that was found to be available at the county level was "percentage of adults who could not see a doctor at least once in the past year due to cost" in 2007 (Florida Behavioral Risk Surveillance System, 2007). This predictor was matched for both demographic groups, that is "percentage of [white female] adults who could not see a doctor at least once in the past year due to cost," and percentage of [all] adults who could not see a doctor at least once in the past year due to cost" (Florida Behavioral Risk Surveillance System, 2007). This predictor is now referred to as "cost."

Analysis

Probability plots for the response variables indicated a distribution that was reasonably normal for both demographic groups. Scatter plots indicated acceptable linearity between dose and response variables for both groups. Thus, multiple linear regression was considered appropriate for these data for both groups and was performed in Stata IC 12.1 (College Station, TX). Initial regression models consisted of:

1. White female cancer death rate as the response variable and temperature, smoking, cost, and land elevation as predictors.
2. All races, both genders cancer death rates as the response variable, while predictors also consisted of temperature, smoking, cost, and land elevation, as well as percent of black persons (including Hispanics), percent of white persons, and percent of Hispanic persons (to test their association with all-races death rates).

Relative strength of predictors was assessed by their semi-partial correlation squared values, which indicate the incremental contributions each predictor makes to the model's R-squared value. The R-squared value indicates the percent of variation in the response variable (cancer death rates in this case) that is explained by the model. Coefficients that have a negative sign represent inverse relationships, where as one variable increases, the other decreases. Positive coefficients (those without a negative sign) represent direct relationships, where the variables increase and decrease in the same direction (expected with most of the predictors in this study, including temperature). P-values less than or equal to the traditional alpha level of 0.05 were considered statistically significant.

RESULTS

Data for all 67 counties were available for all variables (cancer death rates, temperature, smoking, and land elevation) for both groups (white females and all races, both genders). Descriptive statistics are provided in Table 1 while cancer maps are provided in Figures 1-2. These maps show a trend for lower death rates from north-to-south in the state. The temperature map (Figure 3) indicates (as expected) an increase in temperature from north-to-south.

White females

The initial regression model for this group revealed that land elevation and cost were not statistically significant ($p > 0.400$). The final regression model, which omitted these statistically non-significant predictors revealed: a) both remaining predictors to be statistically significant: smoking regression coefficient = 1.1, $p = 0.022$; temperature regression coefficient = -3.4, ($p = 0.002$; and b) model R-squared = 0.315 ($p < 0.0001$). Semi-partial correlation squared values were 0.142 ($p = 0.0005$) for temperature and 0.051 ($p = 0.0328$) for smoking; Table 2).

TABLE 1. Descriptive statistics for all variables, all data (includes outliers). WF = white female. All=all races, both genders. SD = standard deviation.

Variable	n	Mean	SD	Minimum	Maximum
WF-Cancer	67	159.6	21.8	110.3	222.4
All-cancer	67	186.9	34.9	130.5	393.8
WF-Smoke	67	22.4	4.8	12.9	33.4
All-smoke	67	22.2	4.8	14.2	33.6
WF cost	67	15.8	4.8	5.7	26.6
All-cost	65	16.9	4.8	8.1	38.3
Temperature	67	71.2	2.6	67.6	76.6
Elevation	67	62.8	51.2	0	225.7

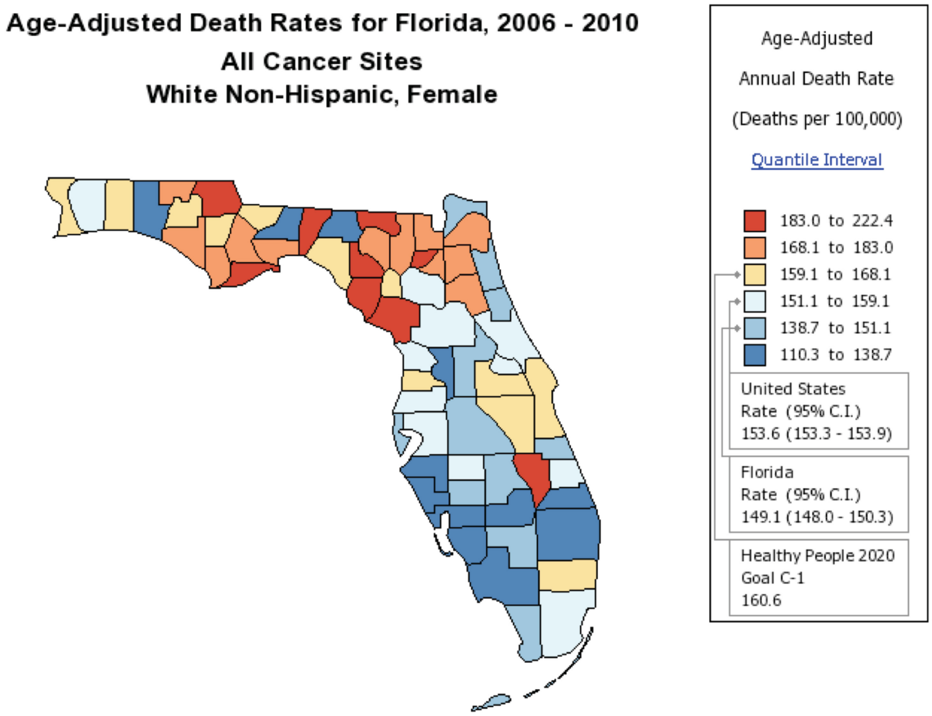

FIGURE 1. Map constructed from online databases at the National Cancer Institute (National Cancer Institute, 2014b).

All races, both genders

An outlier was observed in the scatter plot (Figure 4) for cancer and temperature for this group (Figure 4) due mainly to the high cancer death rate in Union county. Outliers were also observed for the scatter plot for cancer and cost (plot not shown). Consequently, analysis for this group (all races, both genders) was performed *with* and *without* the outliers.

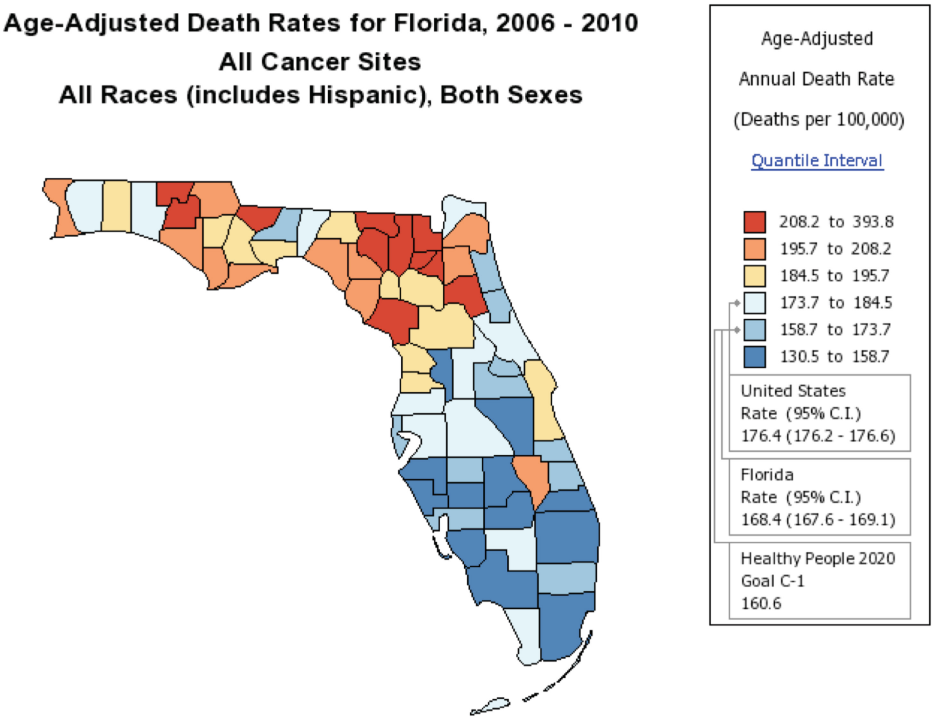

FIGURE 2. Map constructed from online databases at the National Cancer Institute (National Cancer Institute, 2014b).

With the outliers

The initial regression model revealed statistical non-significance for all predictors ($p > 0.09$). The white race predictor revealed the highest amount of collinearity so it was removed in the second regression model, which still revealed statistical non-significance for all remaining predictors ($p > 0.08$). Predictors were removed one-at-a-time, beginning with the largest statistically non-significant p-value. In the final model, remaining predictors that were statistically significant were: a) temperature (regression coefficient = -4.6, $p < 0.001$), and b) smoking (regression coefficient = 2.7, $p = 0.010$). The model R-squared was 0.388, $p < 0.0001$. Semi-partial correlation squared values were 0.090 ($p = 0.0031$) for temperature, and 0.097 ($p = 0.0022$) for smoking (Table 2).

Without the outliers

The only statistically significant predictors that remained for the final regression model were: a) temperature (regression coefficient = -4.4, $p < 0.001$); b) percent Hispanic population (regression coefficient = -0.4, $p = 0.009$); and c) cost (regression coefficient = 2.8, $p < 0.001$; Table 2). The model R-squared value was considerably larger: 0.704, $p < 0.0001$. The semi-partial correlation squared value was largest for cost (0.215, p

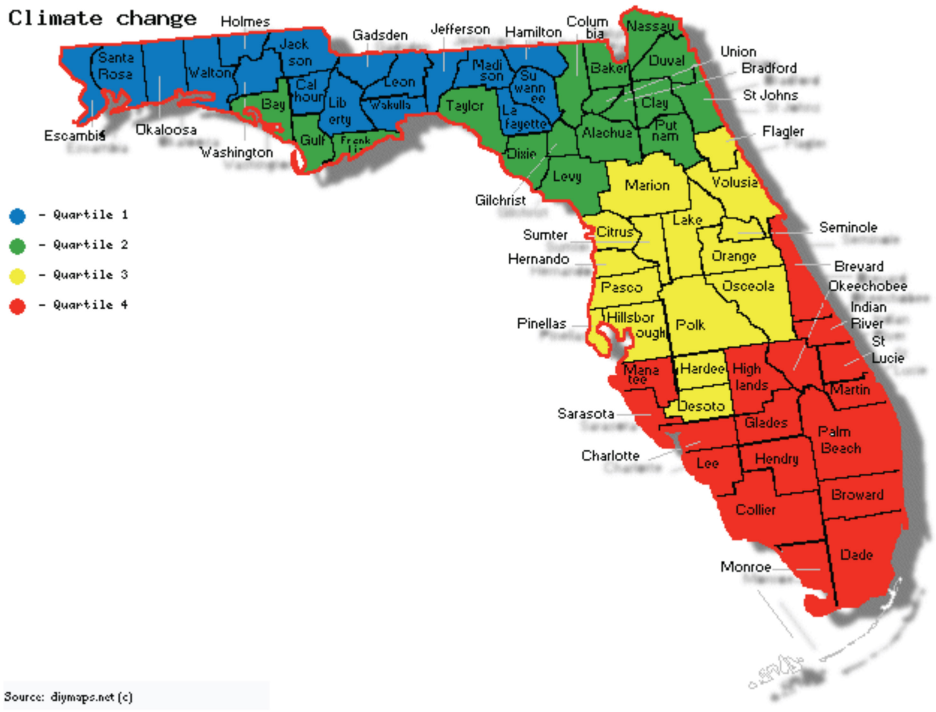

FIGURE 3. Map for air temperature (main predictor in the study), constructed by author at Diymaps.net based on his quartile calculations of the county temperatures, showing "climate change" in Florida from north-to-south. Blue = Quartile 1 (lowest temperature category). Green = quartile 2 (second lowest temperature category). Yellow = quartile 3 (second highest temperature category). Red = quartile 4 (warmest temperature category).

TABLE 2. Final regression models with cancer death rates in Florida as the response variable. n = number of Florida counties. Coef = regression coefficient. The first p value (to the immediate right of Coef), along with the confidence interval (CI) pertain to the regression coefficient. SPC^2 = semi-partial correlation squared. The second p value (to the immediate right of SPC^2) pertains to the SPC^2. Each response variable has two lines of predictors (Smoking and Temperature). Only predictors that were statistically significant in their final models are included here.

Response variable	Predictor	n	Coef	p	95% CI	SPC^2	p
White female cancer	Smoking	67	1.1	0.022	0.2 to 2.1	0.051	0.0328
	Temperature	67	-3.4	0.002	-5.5 to -1.2	0.142	0.0005
All races, both genders (with outliers)	Smoking	67	2.7	0.010	0.7 to 4.7	0.097	0.0022
	Temperature	67	-4.6	<0.001	-6.5 to -2.8	0.090	0.0031
All races, both genders (without outliers)	Smoking	65	1.8	<0.001	0.8 to 2.7	0.092	0.0004
	Temperature	65	-4.4	<0.001	-6.5 to -2.8	0.120	<0.0001
	Cost	65	2.8	<0.001	2.0 to 3.6	0.215	<0.0001
	% Hispanic	65	-0.4	0.009	-0.7 to -0.1	0.019	0.0546

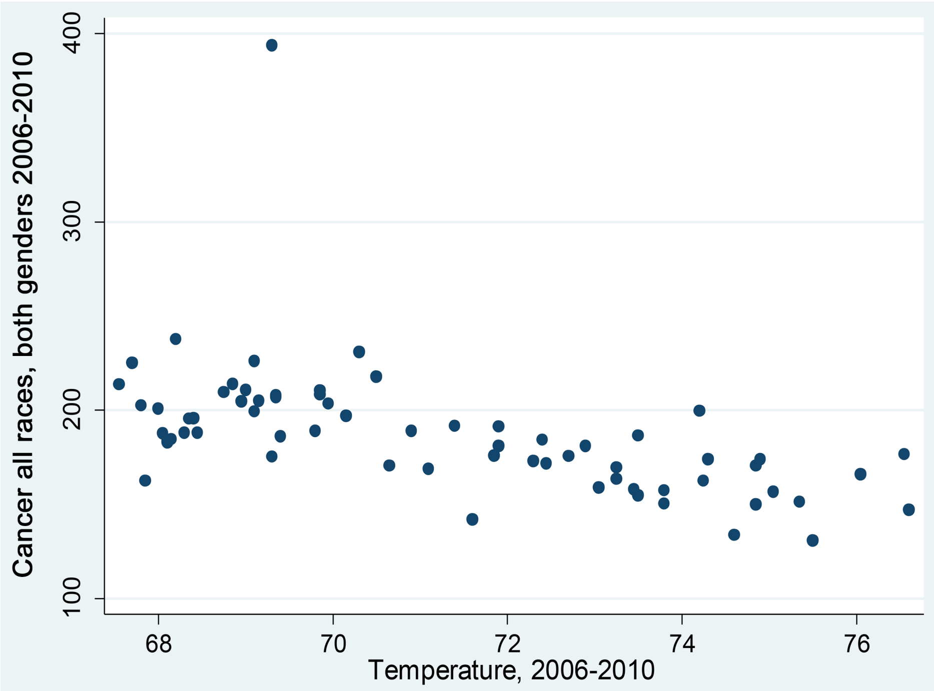

FIGURE 4. Scatter plot for cancer death rates, all races, both genders, versus temperature. An outlier is observed in the upper left hand area of the plot while the reaming data indicate an inverse relationship, where as temperatures increase, cancer death rates decrease.

< 0.0001), second largest for temperature (0.120, p < 0.0001) and smallest, and not quite statistically significant for percent Hispanic population (0.019, p = 0.0546; Table 2).

DISCUSSION

The detrimental association between smoking and the death rates observed in this study was expected. What was unexpected, given the dire predictions about global warming, is the apparent beneficial association between warmer temperatures and the cancer death rates that was revealed in all three regression models.

The variable *cost*, while seemingly limited to health care (as described in Methods), is considered by the author to be a proxy variable for the general ability of people to pay for things that contribute to their good health, for example, through buying healthy food.

Cost and temperature revealed essentially the same strength of prediction according to their semi-partial correlation squared values in one of the models (all races, both genders, without the outliers), However, in the other two models, cost was not a factor while temperature was. Temperature and smoking showed essentially the same strength of prediction in one of the models (all races, both genders, with the outliers) while temperature was a stronger predictor than smoking in the other two models. Thus, temperature appears to be a relatively strong predictor of the cancer death rates in this study.

As an example of how the regression coefficient for temperature is interpreted, for white females, an average of 3.4 fewer deaths per 100,000 persons in the state of Florida are expected per one degree increase within the temperature range in this study (67.6 to 76.6 degrees F).

While other factors also contribute to cancer death rates, this study controlled for several important ones: smoking, land elevation, economics (via the "cost" variable), and race. The variable of temperature "held its own" alongside the other well-known predictors (of smoking, race, and cost). The finding of a benefit from warmer temperatures on the death rates is consistent with a recent report which revealed that warmer temperatures are linked to decreased mortality for cardiovascular disease, strokes, and respiratory disease (Idso *et al*, 2014).

Land elevation, which typically shows an inverse (beneficial) association with cancer death rates (Jagger, 1998; Hart, 2011; Hart, 2014), did not show any statistically significant relationships with the cancer death rates in this study. This may be due to Florida's low variability in land elevation (a relatively low and flat state). There may be a threshold of land elevation difference between regions before a statistically significant association is observed between it and a health outcome such as cancer death rates. In other words, the range for Florida, 0 feet to 345 feet (Florida's lowest and highest points) may be too small of a difference to detect such an association. Previous studies on land elevation typically have not included temperature as a predictor alongside of land elevation. Clearly, more research is needed to determine which factor (land elevation or temperature) has a greater effect on cancer death rates.

The study is limited to the extent that it is a population-based (ecological) study, where doses (of temperatures, smoking habits, and stressors related to land elevation) are unknown for individuals. Still, ecological studies such as this one: a) have the advantage of sample sizes that include essentially the entire population for these race groups tested, b) serve as a springboard for future studies, and c) are used in other important areas of research (e.g., Hahn and Moolgavkar, 1989; Jacobs *et al*, 1992; Kerr-Pontes *et al*, 2004; Myers *et al*, 2006). Another limitation is that other variables related to cancer were not included in this study.

CONCLUSION

This ecological study revealed that warmer air temperatures were associated with lower cancer death rates in Florida counties for the years studied. Further study would help to verify or refute these findings.

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