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Land Elevation, Air Temperature, and Cancer Mortality for selected U.S. Cities

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Abstract

Introduction: *The present study seeks to verify previous research on the association between land elevation, air temperature, and cancer mortality.*
Methods: *Age-adjusted cancer rates (per 100,000 persons) in 2008 were compared to: a) mean monthly temperatures in 2008 and b) land elevations for selected cities in the United States having available cancer mortality data. Individual regression models were performed for each predictor and R-squared values were compared.*
Results: *Temperature predicted approximately 10% of the cancer rate variation, which was not quite statistically significant ($p = 0.097$). Land elevation predicted approximately 40% of the cancer rate variation, and this was statistically significant ($p < 0.001$). The statistically significant predictor, land elevation, showed a regression coefficient of -0.006 (95% confidence interval = -0.01 to -0.002). This indicates that for every 1000 feet increase of land elevation, an average of six fewer deaths per 100,000 persons is predicted (95% CI = 2 to 10 fewer deaths per 100,000 persons).*
Conclusion: *The findings of this ecological study are consistent with previous research showing lower cancer mortality in higher land elevations. Further research with other years will contribute to the evidence base for this relationship.*

Keywords: Altitude, neoplasms, weather, temperature, cities, land elevation, air temperature, and cancer mortality for selected U.S. Cities

Introduction

Previous research has indicated that higher land elevation is associated with lower cancer death rates (Hart, 2013; Jagger, 1998)as well as lower heart disease. (Faeh et al, 2009)Other research suggests that higher altitudes are associated with worse outcomes. (Brenner et al, 2011; West, 2004)The relationship between weather / air temperature and mortality rates is unclear. (McGeehin and Mirabelli, 2001) Curriero et al (2002) found a nonlinear relationship between temperature and mortality risk, where the risk: a) decreased as cold temperatures warmed (from approximately -20 degrees Fahrenheit to +65 degrees F), and then b) increased risk as temperatures increased. Presumably, the stressors that exist at higher altitudes such as increased low level (natural background) radiation and hypoxia are contributing factors to outcomes. Healthier outcomes observed at higher land elevations suggest a triggering beneficial adaptive mechanisms in response to the related low level stressors of low level (background) radiation (e.g., radiation hormesis) (Hart, 2013; Jagger, 1998) and/or hypoxia. (Basovich, 2013)

A previous study compared land elevation of selected cities to corresponding cancer mortality in 2006 and found a moderate strength, statistically significant, inverse correlation (higher land elevations related to lower cancer mortality). (Hart, 2013)The present study repeats the previous study, (Hart, 2013) using a different year: 2008. Both studies used the same cities (with the exception of one

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city whose data was not available in the earlier study) based on available cities with reportable cancer death rates from the Centers for Disease Control and Prevention (CDC). Other differences between the studies are that the present study uses: a) all ages for the cancer death rates, and b) the mean (instead of the median) for the land elevation measurements within a city. Although there are many determinants of cancer, the present study focuses only on two - that are environmental: land elevation and air temperature.

Methods

Study design

The study used an ecological design, where populations, rather than known individuals were studied.

Dependent variable

Age-adjusted cancer death rates per 100,000 persons for 2008 were obtained for all cancer sites combined, all ages, non-Hispanic whites, both genders from CDC Wonder databases. (CDC, 2013) A single race was used since: a) death rates tend to vary by race, and b) different races may reside at different land elevations. The race selected provided the maximum amount of available data. The CDC Wonder databases provide cancer mortality at the state, county, and metropolitan level. It was thought that the smallest area would provide the least amount of variation of land elevation. Consequently, metropolitan areas were selected (instead of county or state areas). Many of the metropolitan areas showed more than one city listed. For example, one metropolitan area consisted of Albany, Schenectady, and Troy, New York as the basis of their average death rate value. Other metropolitan areas had a single city, such as Albuquerque, New Mexico. Thus, in an effort to further minimize land elevation variation in the measurements, only metropolitan listings that consisted of a single city (such as Albuquerque) were selected. The CDC Wonder database provided 32 such (single-reported) cities (Table 1) and these were the cities used in the present study.

Table 1. Cities included in the study, with their cancer death rates (per 100,000) in 2008 ("Cancer"), mean land elevation in feet above sea level ("Elev") and mean monthly air temperature in 2008 ("Temp") in Fahrenheit.

City	Cancer	Elev	Temp
Akron, OH	185.9	1021.0	29.9
Albuquerque, NM	171.2	5417.8	33.4
Bakersfield, CA	197.1	377.8	48.9
Baton Rouge, LA	192.9	46.2	51.7
Colorado Springs, CO	145.8	6418.8	26.7
Columbia, SC	171.5	240.6	45.1
Columbus, OH	187.9	859.4	31.7
Dayton, OH	191.5	796.0	29.1
El Paso, TX	178.7	3966.8	45.2
Fresno, CA	175.2	318.2	46.9
Honolulu, HI	165.6	115.2	68.9
Jackson, MS	170.9	308.6	46.1
Jacksonville, FL	203.8	23.8	52.5
Knoxville, TN	187.0	1036.0	35.6
Lakeland, FL	176.8	152.2	62.9
Lancaster, PA	189.4	364.4	32.4
Madison, WI	170.2	936.4	17.4
Modesto, CA	205.9	91.0	47.6
Oklahoma City, OK	178.4	1196.2	39.9
Pittsburgh, PA	185.7	930.4	31.1
Richmond, VA	176.4	168.0	40.0
Rochester, NY	185.4	450.8	30.4
Salt Lake City, UT	122.7	4425.4	23.9
San Antonio, TX	171.9	803.4	51.8
Springfield, MA	176.8	171.2	NA
Stockton, CA	193.1	17.2	45.9
Syracuse, NY	188.2	510.4	29.5
Toledo, OH	179.4	612.0	NA
Tucson, AZ	157.3	2665.8	51.7
Tulsa, OK	187.0	667.8	38.5
Wichita, KS	177.5	1327.6	32.6
Worcester, MA	192.4	602.0	27.9
Mean	179.4	1157.5	39.8
SD	16.3	1621.0	11.9

Independent variables

Land elevations, measured in feet above sea level, were obtained by the author as before (Hart, 2013) with Google Earth using the computer's mouse to point to locations within each city. Five such points, in the form of a plus sign were measured, as follows: left middle, upper middle, right middle, lower middle, and center. The mean of the five measurements for each city was compared to its corresponding cancer death rate. Data for one city, Lancaster, Pennsylvania was not available in the earlier study (Hart, 2013) but available in the present study so new measurements were obtained for this city.

Average monthly temperatures in 2008 were obtained from weather-warehouse.com, a website by meteorologists having data from the National Weather Service. (Weather, 2013) Two of the 32 cities

(Springfield, Massachusetts; and Toledo, Ohio) did not have temperatures reported. Thus, for the present study, comparisons were made for: a) cancer and corresponding land elevations (n = 32 cities), and b) cancer and corresponding temperatures (n = 30 cities).

Data analysis

The dependent variable showed a reasonable degree of normality in its probability plot (Figure 1). In regression analysis, the automatic model selection in Minitab 16.1.1 (Minitab Inc, State College, PA) selected two different model types for the two different predictors (based on strength of their R-squared values): linear for cancer and elevation (Figure 2) and quadratic for cancer and temperature (Figure 3). Since Minitab easily performs quadratic regression, it was used for the cancer - temperature model. To cope with the marked unequal variance noted in the cancer - land elevation scatter plot (Figure 2), Stata 12.1 was used with its “robust” option in the regression command. The R-squared and p-values from the two models were compared to determine which predictor, if either, had a stronger association with the cancer rates. Two-tailed p-values less than or equal to the traditional alpha level of 0.05 were considered statistically significant. Regression coefficients are reported and interpreted for predictors that are statistically significant.

Figure 1.Probability plot for the dependent variable, cancer mortality.

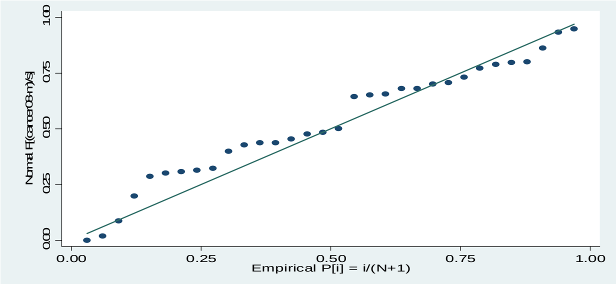


Figure 2. Scatter plot of cancer mortality and land elevation for 32 cities.

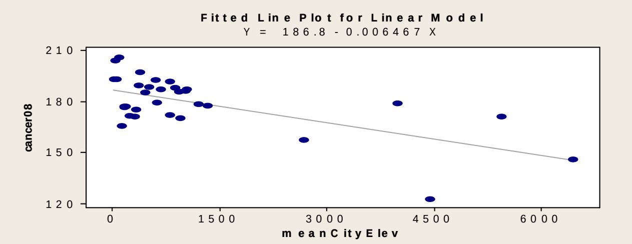
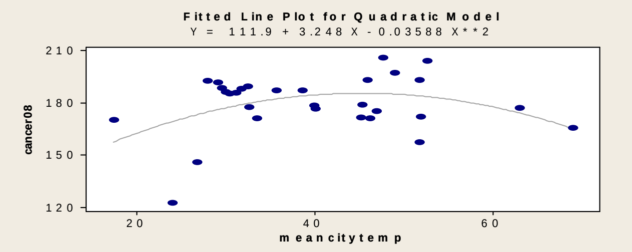


Figure 3. Scatter plot of cancer mortality and mean temperatures in 2008 for 30 cities.



Results

For temperature, the adjusted R-squared value was 0.097, indicating that the model explained approximately 10% of the variation in cancer deaths for these cities, but the predictor was not quite statistically significant (p = 0.097; Table 2).

For land elevation, the R-squared value was 0.416 (p = 0.003) indicating that the model explained approximately 41% of the variation in cancer deaths for these cities. The regression coefficient for land elevation was -0.006 (95% confidence interval = -0.01 to -0.002). This indicates that for every 1000 feet increase in land elevation, an average of six fewer deaths per 100,000 persons is expected (95% confidence interval = 2 to 10 fewer deaths per 100,000 persons). When omitting the two cities in the land elevation analysis that were omitted in the temperature analysis (due to unavailable temperatures), the results for land elevation were essentially unchanged (linear model automatically selected; adjusted R-squared = 0.428, p = 0.003; regression coefficient = -0.007, 95% confidence interval = -0.01 to -0.002).

Table 2. Linear regression results with 2008 cancer death rates as the dependent variable. n = number of cities.

Predictor	n	Model	R-squared	p-value
Land elevation	32	Linear	0.396	0.000
Temperature	30	Quadratic	0.097	0.097

Discussion

Obviously there are many determinants of cancer such as genetics and behaviors. This ecological study focused on two possible environmental factors, that of land elevation and air temperature. The present study found a statistically significant inverse relationship for land elevation (higher elevations associated with lower cancer mortality), which is consistent with the previous similar study that used an earlier year. (Hart, 2013)

Though not statistically significant, the nonlinear relationship between cancer death rates and temperature in the present study is similar to that of Curriero et al (2002) who observed a J-shape relationship. The present study is also consistent with the findings of Youk et al (2012) who also found lower cancer mortality in the higher altitudes (at the county level). Their hypothesis (Youk et al, 2012) was that low hemoglobin at the higher altitude affects cancer mortality.

Land elevation is a proxy variable for other more specific variables such as: a) low level (natural background radiation) and b) oxygen concentration. Both of these are stressors that may trigger beneficial adaptive responses in the human body. (Hart, 2013; Jagger, 1998; Basovich, 2013) In the case of low level radiation, increased land elevation corresponds to increased amounts of low level (natural background) radiation. It is estimated that an annual dose of 2 millirem (mrem) of this type of low level ionizing radiation (due to land elevation alone)per year corresponds to elevations up to 1000 feet;5 mrem for 1000-5000 feet; and 9 mrem for 2000-3000 feet, and so on. (U.S., 2013a)Interpretation with greater precision indicates that for every 200 feet increase of land elevation, an annual increase of 1 mrem is expected. (U.S., 2013b)To get some perspective of these exposure numbers, total natural background radiation for a one year period is approximately 300 mrem, while two chest x-rays produce an exposure that is approximately equivalent to 6 mrem whole body exposure to the whole body. (Health, 2013) In the case of oxygen concentration, percentage of oxygen in the air (compared to percent at sea level) decreases as altitude (land elevation) increases. For example, at approximately 18,000 feet (5500 meters), 50% of oxygen is present in the air compared to sea level; at approximately 29,000 feet (8900 meters), the concentration drops to 30%. (Peacock, 1998)

Limitations to the study are: a) its (ecological design), b) non-random sampling of all cities in the United States, and c) a non-accounting of other possible factors related to cancer.

Conclusion

This ecological study found that cancer death rates for these 32 U.S. cities tended to be lower in cites with higher land elevations, and this is consistent with previous research on this topic. Ongoing research for other years will add to the evidence base for the land elevation – cancer mortality hypothesis.

References

Basovich, SN.(2013). Trends in the use of preconditioning to hypoxia for early prevention of future life diseases. BioScience Trends, 7(1), 23-32.

Brenner, B., Cheng, D., Clark, S., Camargo, CA.(2011). Positive association between altitude and suicide in 2584 U.S. counties. High Alt Med Biol, 12(1), 31-35.

CDC Wonder. United States Cancer Statistics, 1999-2009 Mortality Results. Centers for Disease Control and Prevention.(2013). [Cited 2013 Dec 3]. Available from: www.wonder.cdc.gov

Curriero, F., Heiner, K.S., Samet, J.M., Zeger, S.L., Strug, L., Patz, J.A.(2002).Temperature and mortality in 11 cities of the eastern United States. Am J Epidemiol,155, 80-87.

Faeh, D., Gutzwiller, F., Bopp, M. (2009).Lower mortality from coronary heart disease at higher altitudes in Switzerland. Circulation, 120, 495-501.

Hart, J. (2013). Land elevation and cancer mortality in U.S. cities and counties using median elevations derived from geographic information systems. Dose-Response, 11(1), 41-48.

Health Physics Society: Doses from Medical X-Ray Procedures. (2013). [Cited 2013 Dec 4]. Available at: http://hps.org/physicians/documents/Doses_from_Medical_X-Ray_Procedures.pdf

Jagger, J.(1998).Natural background radiation and cancer death in Rocky Mountain States and Gulf Coast states.Health Phys, 75(4), 428-430.

McGeehin, M.A., Mirabelli, M. (2001).The potential impacts of climate variability and change on temperature-related morbidity and mortality in the United States. Environ Health Perspect, 109, 185-189 [suppl 2].

Peacock, A.J. (1998).Oxygen at high altitude. Brit Med J, 317(7165), 1063-1066.

U.S. Environmental Protection Agency: Calculate your radiation dose. 2013a. [Cited 2013 Nov 28]. Available at: www.epa.gov

U.S. Department of Energy: Low dose radiation research program. 2013b. Background radiation. [Cited 2013 Dec 9]. Available at: http://lowdose.energy.gov/pdf/Powerpoint_Background.pdf

Weather-Warehouse: Historical monthly weather data. [Cited 2013 Dec 7]. Available at: www.weather-warehouse.com

West, JB. (2004).The physiological basis of high altitude diseases. Ann Intern Med, 141, 789-800.

Youk, A.O., Cuchanich, J.M., Fryzek, J., Cunningham, M., Marsh, G.M. (2012). An ecological study of cancer mortality rates in high altitudes counties of the United States. High Alt Med Biol, 13(2), 98-104.