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HEART DISEASE DEATH RATES IN LOW VERSUS HIGH LAND ELEVATION COUNTIES IN THE U.S.

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□ Previous research on land elevation and cancer death rates in the U.S. revealed lower cancer death rates in higher elevations. The present study further tests the possible effect of land elevation on a diffident health outcome, namely, heart disease death rates. U.S. counties not overlapping in their land elevations according to their lowest and highest elevation points were identified. Using an ecological design, heart disease death rates for two races (black and white) corresponding to lower elevation counties were compared to heart disease death rates in higher land elevation counties using the two-sample t-test and effect size statistics. Death rates in higher land elevation counties for both races were lower compared to the death rates in lower land elevation counties ($p < 0.001$) with large effect sizes (of > 0.70). Since this is an observational study, no causal inference is claimed, and further research is indicated to verify these findings.

Keywords: Altitude, heart disease, death rates, epidemiologic methods

INTRODUCTION

Previous research using an ecological design has indicated that cancer death rates tended to be lower in higher altitude (land elevation) areas in the U.S. (Jagger, 1998; Hart, 2011). The reason for this may pertain to the body's successful adaptation to environmental stressors that accompany higher land elevations. These stressors include: a) higher levels of cosmic low level radiation, and b) decreased oxygen concentration. A breakdown by cancer type however, may show a different clinical picture for particular types of cancer. For example, a higher incidence of prostate cancer has been observed in more northern areas in the U.S. (that typically have higher land elevations) compared to southern areas (St-Hilaire *et al*, 2010).

The present study compares possible health effects of land elevation in regard to a to a different health outcome – heart disease death rates, using the author's method of identifying *low* versus *high* land elevation states in the U.S. The method allows for a comparison of health outcomes (such as heart disease death rates) corresponding to areas that clearly do not overlap in their respective land elevations. A previous study used the method to compare cancer death rates (all cancer sites) and found lower

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death rates in higher elevation areas (Hart, 2014), similar to the aforementioned study on cancer death rates (Jagger, 1998; Hart, 2011).

Low level radiation, which, as previously noted, increases with increasing altitude (due to less atmospheric filter) has been claimed to be a factor in cardiovascular disease (Little *et al*, 2012). Thus, the present study tests this claim. As with the previous study, (Hart, 2014) an attempt is made at the population level to account for the variable of smoking since this is a notable determinant of heart disease (CDC, 2014a).

METHODS

Dose variable

The "dose" variable in this study was land elevation (in feet above sea level) – a proxy variable for the environmental stressors that accompany land elevations (such as low level cosmic radiation and oxygen concentration). The 50 states and District of Columbia (all now referred to as "states") were sorted according to lowest land elevation points, while also noting their corresponding highest points (U.S. Census Bureau, 2011). Sixteen states were identified as having non-overlapping land elevations, 11 of which were categorized as "low" elevation while the remaining five were categorized as "high" elevation (Table 1). As additional explanation of how states were included or excluded in the present study, the next highest elevation point in Table 1 after Missouri's highest point of 1772 feet is New Jersey's highest point of 1803 feet (New Jersey's lowest point

TABLE 1. Descriptive statistics. 51 jurisdictions with their highest ("high" column) and lowest ("low" column) land elevation points. Three land elevation categories in the "Elevation" column as low, overlap, and high. D.C. = District of Columbia. Smoke-w = percent of white adults who were smokers in 2008. Smoke-b = percent of black adults who were smokers in 2008 in non-overlapping states for land elevation (rows "low" and "high"). Lower and upper fences pertain to outlier analysis for smoking for non-overlapping land elevation states. Bolded values in Smoke columns indicate outlier states which were omitted from *t* test analysis. NA = data not reported in source used (Centers, 2014c).

Row	Elevation	State	High	Low	Smoke-w	Smoke-b
1.	Low	Florida	345	0	19.5	12.7
2.	Low	D.C.	410	1	**9.8**	22.4
3.	Low	Delaware	448	0	17.9	16.5
4.	Low	Louisiana	535	-8	21.0	19.9
5.	Low	Mississippi	806	0	23.5	20.6
6.	Low	Rhode Island	812	0	17.8	16.5
7.	Low	Illinois	1235	279	19.9	25.7
8.	Low	Indiana	1257	320	24.5	33.3
9.	Low	Ohio	1550	455	18.9	24.3
10.	Low	Iowa	1670	480	18.1	NA
11.	Low	Missouri	1772	230	24.9	24.7

continued

TABLE 1. *Continued*

Row	Elevation	State	High	Low	Smoke-w	Smoke-b
12.	Overlap	New Jersey	1803	0		
13.	Overlap	Wisconsin	1951	579		
14.	Overlap	Michigan	1979	571		
15.	Overlap	Minnesota	2301	601		
16.	Overlap	Connecticut	2380	0		
17.	Overlap	Alabama	2407	0		
18.	Overlap	Arkansas	2753	55		
19.	Overlap	Pennsylvania	3213	0		
20.	Overlap	Maryland	3360	0		
21.	Overlap	Massachusetts	3491	0		
22.	Overlap	North Dakota	3506	750		
23.	Overlap	South Carolina	3560	0		
24.	Overlap	Kansas	4039	679		
25.	Overlap	Kentucky	4145	257		
26.	Overlap	Vermont	4393	95		
27.	Overlap	Georgia	4784	0		
28.	Overlap	West Virginia	4863	240		
29.	Overlap	Oklahoma	4973	289		
30.	Overlap	Maine	5268	0		
31.	Overlap	New York	5344	0		
32.	Overlap	Nebraska	5424	840		
33.	Overlap	Virginia	5729	0		
34.	Overlap	New Hampshire	6288	0		
35.	Overlap	Tennessee	6643	178		
36.	Overlap	North Carolina	6684	0		
37.	Overlap	South Dakota	7242	966		
38.	Overlap	Texas	8749	0		
39.	Overlap	Oregon	11239	0		
40.	Overlap	Arizona	12633	70		
41.	Overlap	Idaho	12662	710		
42.	Overlap	Nevada	13140	479		
43.	Overlap	Hawaii	13796	0		
44.	Overlap	Washington	14411	0		
45.	Overlap	California	14494	-282		
46.	Overlap	Alaska	20320	0		
47.	High	Montana	12799	1800	17.2	NA
48.	High	New Mexico	13161	2842	19.4	NA
49.	High	Utah	13528	2000	**8.8**	NA
50.	High	Wyoming	13804	3099	18.3	NA
51.	High	Colorado	14433	3315	16.0	27.9
Lower fence					13.86	7.70
Upper fence					23.96	35.70

= 0 feet). However, New Jersey would overlap (slightly) with Montana's lowest point of 1800 feet (Montana in the high land elevation category). All other states would also overlap with at least Montana. Montana could have been included in the low land elevation category but that would have increased the lob-sided county counts between low and high land elevation categories, even though the statistical test used in this study (the two-sample *t* test) does not require an equal number of observations in

each sample. Missouri, with the highest high elevation point in the low land elevation category, could have been included in the high land elevation category, but its lower elevation points would have overlapped with the lower land elevation points in many of the other low land elevation states (Table 1). Thus, the best "cut-points" were considered to be 1772 feet for low land elevation states and 1800 feet for high land elevation states (Table 1). A land elevation map is provided in Figure 1.

Response variable

The response variable was age-adjusted heart disease death rates (HDDR) per 100,000 persons for 2008-2010 (the most recent set of available years at the time of this study), all ages, both genders, data spatially smoothed for all reporting counties, for two race groups: a) black non-Hispanic and b) white non-Hispanic (Figures 2 and 3, CDC, 2014b). The reason for studying races separately is because death rates tend to be different for different races.

Smoking

Mean percent of adults who were smokers in 2008 (CDC, 2014c) in the 16 states were analyzed for outliers, at the state level, using the method that: a) multiplies the inter-quartile range by a factor of 1.5, and then b) calculates lower and upper limits ("fences"). Smoking rates were available for all 16 states for white persons. For black persons, smoking

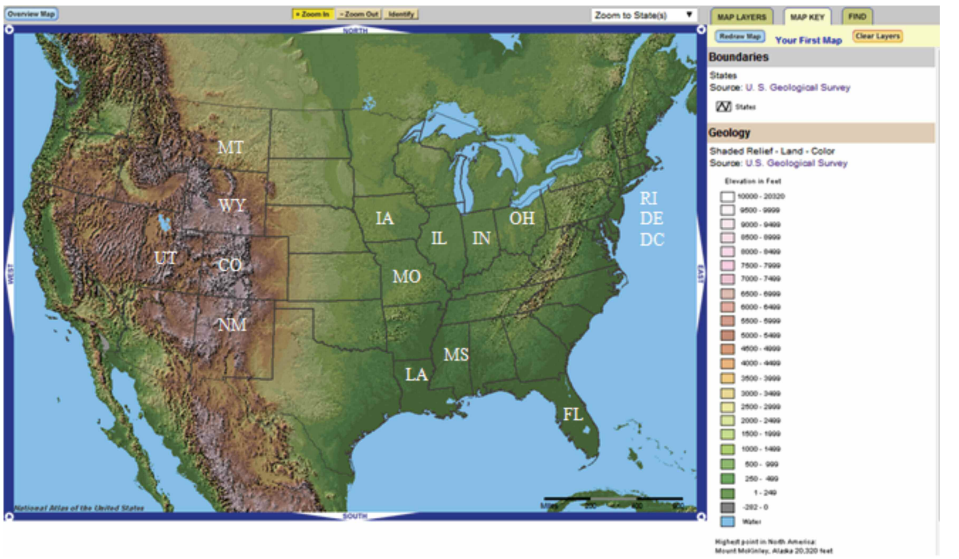

FIGURE 1. U.S. Geological Survey land elevation map, constructed at www.nationalatlas.gov. Low land elevations located in Gulf Coast states have higher HDDR compared to Rocky Mountain states (as noted in maps in Figures 2-3). (Note: Map includes state abbreviations for low versus high states.)

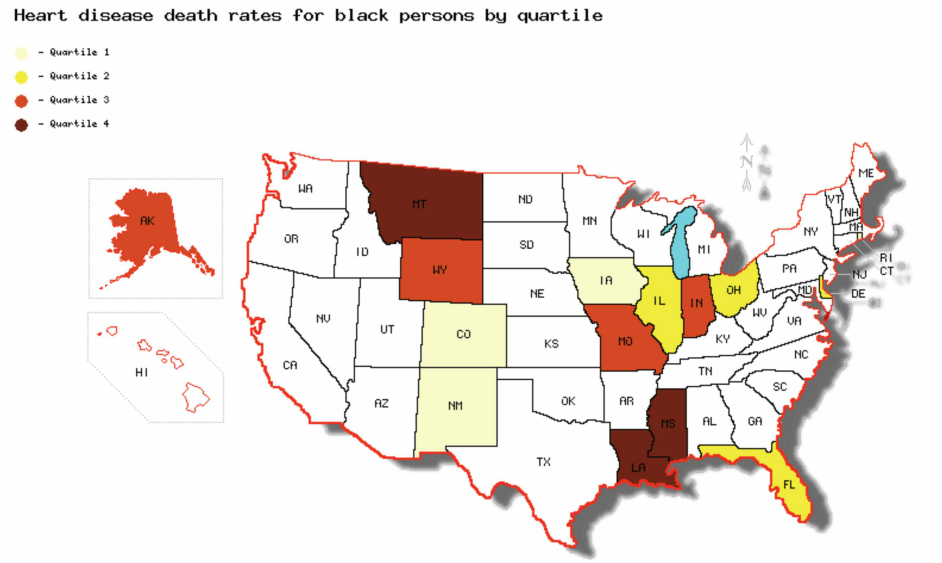

FIGURE 2. Mean HDDR map for black persons. Constructed at Diymaps.net (2014)

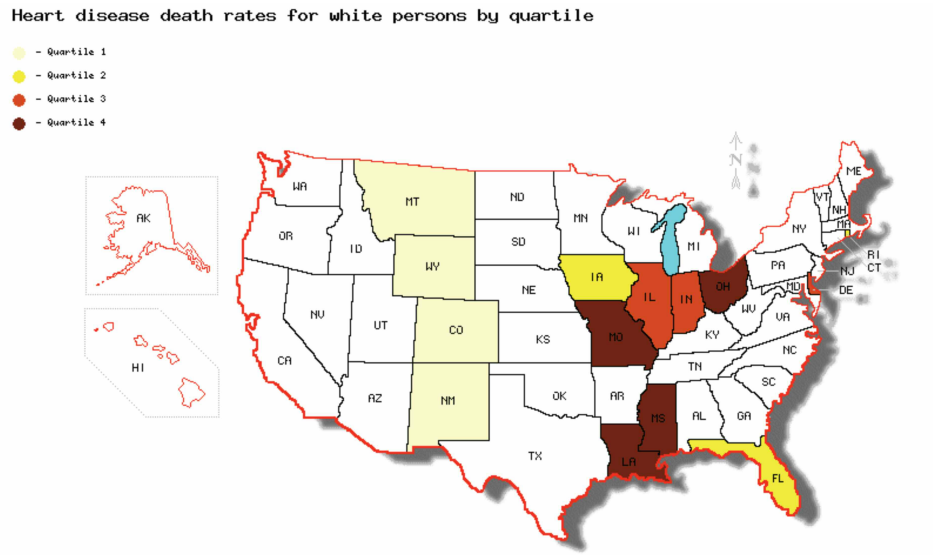

FIGURE 3. Mean HDDR map for white persons. Constructed at Diymaps.net (2014)

rates were available for all low land elevations states except Iowa, and for only one state in the high land elevation category – Colorado. Smoking outliers were omitted from the final analysis. States with missing smoke data were excluded if the smoking rate for the other race was an outlier, inferring from one race category to the other for smoking behaviors.

Analysis

The final (inferential) analysis consisted of comparing HDDR in low elevation counties to HDDR in high land elevation counties for the two race groups. The two sample *t* test with the unequal variances option was used in Stata IC 12.1 (StataCorp, College Station, TX) to compare the two HDDR groups (corresponding to low versus high land elevation counties). The *t* test was considered appropriate since the number of observations (counties) in each land elevation category was at least 30 (Devore and Peck, 2005). P-values less than or equal to the traditional alpha level of 0.05 were considered statistically significant. Comparisons that were statistically significant were further tested with an effect size statistic, using pooled standard deviation (Morgan *et al*, 2007) to assess the magnitude of the difference.

RESULTS

Smoking

Utah and District of Columbia were (low) outliers for smoking for the white race (Table 1). No outliers were observed for states reporting smoking rates for the black race (Table 1). Since Utah did not report smoking data for the black race, and since it was an outlier for the white race, Utah was also omitted for the black race. The District of Columbia was omitted for the white race because it too was a smoking outlier.

HDDR

For black persons, mean HDDR in low land elevations (n = 576 counties) was 245.2 (standard deviation [SD] = 73.7, 95% confidence interval [CI] =239.1 to 251.2) compared to mean HDDR in high land elevations (n = 51 counties) of 190.2 (SD = 89.9, 95% CI = 164.9 to 215.5), a difference that was statistically significant (p = 0.0001) with a large effect size (of 0.73; Table 2).

For white persons, mean HDDR in low land elevations (n = 717 counties) was 210.2 (SD = 42.3, 95% CI = 207.1 to 213.3) compared to mean HDDR of 157.6 (SD = 28.7, 95% CI = 153.3 to 161.8) in high land elevations (n = 176 counties), a difference that was statistically significant (p < 0.0001) with a very large effect size (of 1.32; Table 2).

DISCUSSION

The results in this study for heart disease death rates and land elevation are similar to results for previous studies on land elevation and cancer death rates – that found lower cancer death rates in higher land elevations (Jagger, 1998; Hart, 2011; Hart, 2014). This further suggests that altitude-related stressors such as decreased oxygen concentration and

TABLE 2. Inferential statistics. Elevation = land elevation category. n = number of counties. Mean = heart disease death rate mean. SD = standard deviation. CI = confidence interval. p = p value. ES = effect size.

Race	Elevation	n	Mean	SD	95% CI	Mean difference	p	ES
Black	Low	576	245.2	73.7	239.1 to 251.2			
Black	High	51	190.2	89.9	164.9 to 215.5	55.0	0.0001	0.73
White	Low	717	210.2	42.3	207.1 to 213.3			
White	High	176	157.6	28.7	153.3 to 161.8	52.6	< 0.0001	1.32

increased amount of cosmic (low level) background radiation may trigger beneficial adaptive responses in regard to these two top causes of death in the U.S. (heart disease and cancer). Further, the claim by Little *et al* (2012) that low level radiation (represented in the present study by the proxy variable land elevation) is a contributing factor in heart disease, is not supported by the results of this study. Nonetheless, not all studies on health effects of higher altitude living indicate the presence of protective effects (St.-Hilaire *et al*, 2010; Ezzati *et al*, 2012).

Regarding the stressor of increased cosmic low level radiation, the amount of this type of radiation corresponding to altitude changes is estimated to be: 2 millirem (mr) up to 1000 feet in LE, 5 mr for 1000-2000 feet, 9 mr for 2000-3000 feet, and so on (USEPA, 2013). Certainly at some point of increasing amounts of radiation, the radiation becomes harmful or even lethal, depending upon the high level of radiation. In the low level ranges though, a beneficial adaptation may occur as described with *radiation hormesis* (Luckey, 2006).

The accounting of smoking would seem to add credibility to the findings of this study. Limitations to the study include its (ecological) design, where populations rather than known individuals are studied. Nonetheless, ecological designs have an advantage over other designs where individuals are the focus. For example, ecological studies can include entire populations, numbering in the millions, whereas studies of known individuals typically number only up to the hundreds or thousands. Nonetheless, since this is an observational study, no causal inference is claimed.

CONCLUSION

This ecological study found lower heart disease death rates in higher land elevation counties. This suggests the presence of successful adaptation to environmental stressors that accompany higher altitudes. Further research is warranted to verify these findings.

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