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Racial Disparities in Diabetes Mortality in the 50 Most Populous US Cities

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ABSTRACT *While studies have consistently shown that in the USA, non-Hispanic Blacks (Blacks) have higher diabetes prevalence, complication and death rates than non-Hispanic Whites (Whites), there are no studies that compare disparities in diabetes mortality across the largest US cities. This study presents and compares Black/White age-adjusted diabetes mortality rate ratios (RRs), calculated using national death files and census data, for the 50 most populous US cities. Relationships between city-level diabetes mortality RRs and 12 ecological variables were explored using bivariate correlation analyses. Multivariate analyses were conducted using negative binomial regression to examine how much of the disparity could be explained by these variables. Blacks had statistically significantly higher mortality rates compared to Whites in 39 of the 41 cities included in analyses, with statistically significant rate ratios ranging from 1.57 (95 % CI: 1.33–1.86) in Baltimore to 3.78 (95 % CI: 2.84–5.02) in Washington, DC. Analyses showed that economic inequality was strongly correlated with the diabetes mortality disparity, driven by differences in White poverty levels. This was followed by segregation. Multivariate analyses showed that adjusting for Black/White poverty alone explained 58.5 % of the disparity. Adjusting for Black/White poverty and segregation explained 72.6 % of the disparity. This study emphasizes the role that inequalities in social and economic determinants, rather than for example poverty on its own, play in Black/White diabetes mortality disparities. It also highlights how the magnitude of the disparity and the factors that influence it can vary greatly across cities, underscoring the importance of using local data to identify context specific barriers and develop effective interventions to eliminate health disparities.*

KEYWORDS *Large cities, Diabetes, Mortality, Race, Disparities, Economic inequality, Segregation*

INTRODUCTION

Diabetes remains a leading cause of illness and death in the USA. It affected more than 25 million people and caused over 71,000 deaths in 2007.[1] While diabetes prevalence continues to increase throughout the USA, it disproportionately affects minority populations.[2–7] Studies have consistently shown that non-Hispanic Blacks (referred to here as Blacks) are more likely to be diagnosed with diabetes (1.4–2.2 times more likely) and at least twice as likely to die due to diabetes than non-Hispanic Whites (referred to here as Whites).[5,8,9] Blacks are also two to four times

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more likely to experience diabetes-related complications such as lower extremity amputation, renal or eye disease.[7]

Extensive literature attempts to describe why Blacks have higher diabetes prevalence, complication and mortality rates compared to Whites.[5,10–15] The disparity has remained virtually unchanged for nearly 20 years. Blacks were 2.1 times more likely to die due to diabetes than Whites in 1990 and 2.2 times more likely to die in 2009.[16,17] Disparities in diabetes mortality have been examined extensively at the national level and in some individual cities.[18–20] There is no study to our knowledge, however, that systematically compares Black/White diabetes mortality across US cities, using consistent methodology and common data sources. Examining disparities at the city-level, rather than the national level, not only exploits important context specific differences, but can lead to local level community engagement and intervention.[21] This study investigates Black/White racial disparities in diabetes mortality in the 50 most populous US cities, providing city-level comparisons and possible ecological explanations for observed disparities.

METHODS

City Selection

The 50 most populous US cities were identified for inclusion in this analysis using Census data (American Community Survey (ACS) 2005-2007 3-year estimates).[22] Nine cities were excluded. Data were not available at the city-level for Honolulu CDP, HI; Louisville/Jefferson County, KY; and Nashville/Davidson, TN. Mortality data were not available for San Juan, Puerto Rico. Finally, Albuquerque, NM; Colorado Springs, CO; El Paso, TX; Mesa and Tucson, AZ had fewer than 20 Black deaths, the established cutoff for stable estimates, due to small Black population size. There were no cities with fewer than 20 White deaths. This left 41 cities for analysis.[23,24]

Age-Adjusted Diabetes Mortality Rates

Age-adjusted diabetes mortality rates per 100,000 population (using the 2000 US standard population age distribution) were calculated by race at the city-level.[25] Only deaths for which diabetes was identified as the underlying cause were included in this analysis (ICD-10 codes E10-14).[26] Numerator data, at the city-level, were abstracted from national vital records files (2005, 2006, and 2007) provided by the Centers for Disease Control and Prevention. White population estimates by age, for use in the denominator, were obtained for each city from ACS 2005–2007 3-year estimates data.[22] Black population estimates were not available at the city-level according to age. Age-specific Black population estimates were calculated by applying the proportion of the population in each age group in the 2000 census data to the 2005–2007 ACS city-level population estimates.[22,27] This methodology was previously used by Whitman et al.[28]

Statistical Analyses

Age-Adjusted Rate Ratios and Annual Excess Black Diabetes Deaths Black/White age-adjusted diabetes mortality rate ratios (RRs) were used as the measure of disparity and 95 % confidence intervals were calculated using the Taylor series expansion technique.[29] The number of annual excess Black deaths was also calculated for each city.[30]

Bivariate Analyses

Statistical analyses were carried out using Stata 12.[31] Bivariate regression and correlation analyses were used to examine the relationships between city-level diabetes mortality rate ratios and 12 ecological variables (Table 3 contains full list). All but one of the ecological variables were obtained from 2005 to 2007 ACS 3-year estimates data.[22] The Index of Isolation was obtained from Brown University's Spatial Structures in Social Sciences Databases.[32] It uses census data to calculate the probability that a typical person of a given race resides in a census tract with people of the same race and is used as a measure of segregation.[33,34]

Median Household Income and Percent Living Below the Poverty Line Interpolations Due to limitations of ACS data, race-specific Median household income (MHHI) and the percent population living below the poverty line were missing for 12 of the cities included in this analysis. Linear regression models, using census data from 2000 and 2010, were used to estimate what the MHHI and percent population living below the poverty line would have been in 2006 (the midpoint year for this analysis) for these 12 cities.

Multivariate Analyses Multivariate analyses were conducted using negative binomial regression with number of diabetes deaths (by city, age, and race) as the outcome and race as the primary covariate.[35] We examined how ecological variables impacted the relationship between race and mortality. City-level variables that were statistically significantly correlated in bivariate analyses at the 10 % level were tested in the model. Because the Gini index does not vary by race, it was only included in bivariate analyses. Sampling weights were included using the 2000 US standard population age distribution.[25] The natural log of the population size (by city, age and race) was used as the offset. Variance was adjusted for clustering by city. The percent disparity explained by each model was calculated using the following formula[36]:

$$(\mathrm{RR}(\text{race alone}) - \mathrm{RR}(\text{adjusted}))/(\mathrm{RR}(\text{race alone}) - 1)$$

RESULTS

Diabetes Mortality Rates

The overall diabetes mortality rate in the USA (2005–2007 3-year average) was 23.6/100,000 population (Table 1). When stratified by race, the White diabetes mortality rate was 20.8 and the Black rate was 44.4, giving a rate ratio of 2.13 (95 % CI: 2.11–2.16). At the city-level, there were large variations in mortality rates throughout the USA, ranging from a low of 12.5 in San Francisco to a high of 39.7 in Fresno. Table 1 presents mortality rates at the city-level in descending order of Black/White diabetes mortality rate ratios for 41 of the 50 most populous US cities. When stratified by race, there was even greater variability. All cities included in this analysis had Black mortality rates greater than the national average of 23.6. Of the 41 cities included in this analysis, 32 had Black mortality rates that exceeded the highest White mortality rate (Cleveland (34.5)) (Table 1).

TABLE 1 Estimates (3-year) of non-Hispanic Black/non-Hispanic White diabetes mortality disparity in the 50 most populous US cities, 2005–2007 (*N*=41)

US cities (in order of descending Black/ White diabetes mortality rate ratio)	Mortality rate (any race)	Mortality rate White	Mortality rate Black	Mortality rate ratio Black/ White[a]	95%CI		Annual excess Black deaths
United States	23.64	20.79	44.38	*2.13*	2.11	2.16	6798.70
Washington, DC	30.17	10.90	41.18	*3.78*	2.84	5.02	112.36
San Francisco, CA	12.53	9.39	34.04	*3.62*	2.65	4.96	15.33
San Diego, CA	19.92	15.14	54.66	*3.61*	2.89	4.50	25.97
Omaha, NE	28.56	23.09	82.53	*3.57*	2.76	4.62	19.58
Seattle, WA	22.54	18.83	64.82	*3.44*	2.64	4.49	18.51
Phoenix, AZ	19.38	15.18	48.93	*3.22*	2.45	4.25	15.09
Dallas, TX	24.92	15.52	45.49	*2.93*	2.47	3.49	70.42
New York City, NY	20.14	12.54	36.58	*2.92*	2.73	3.12	441.89
Los Angeles, CA	27.97	18.49	53.09	*2.87*	2.59	3.18	134.23
Memphis, TN	35.93	19.10	52.42	*2.74*	2.28	3.30	93.77
Oakland, CA	29.37	16.65	44.66	*2.68*	1.94	3.70	37.20
Kansas City, MO	25.11	17.05	45.28	*2.66*	2.11	3.35	32.02
Oklahoma City, OK	25.58	21.91	57.32	*2.62*	2.06	3.32	20.55
Arlington, TX	21.21	19.16	48.93	*2.55*	1.53	4.27	4.63
Fresno, CA	39.72	28.52	72.52	*2.54*	1.87	3.47	10.82
Houston, TX	28.53	18.52	46.08	*2.49*	2.19	2.83	113.11
Tulsa, OK	26.77	23.02	56.87	*2.47*	1.89	3.23	15.30
Portland, OR	36.01	33.78	82.63	*2.45*	1.89	3.17	14.22
Indianapolis, IN	26.53	20.59	49.45	*2.4*	2.02	2.85	44.00
Denver, CO	16.48	12.27	28.85	*2.35*	1.69	3.28	9.91
Charlotte, NC	21.84	16.25	38.1	*2.34*	1.86	2.96	29.17
Wichita, KS	25.52	22.09	51.36	*2.33*	1.69	3.20	10.08
Austin, TX	23.02	16.53	37.00	*2.24*	1.61	3.11	9.36
Columbus, OH	34.03	26.53	58.52	*2.21*	1.86	2.62	43.39
Minneapolis, MN	25.69	21.42	46.69	*2.18*	1.55	3.06	8.50
Long Beach, CA	25.49	21.73	47.24	*2.17*	1.57	3.01	9.80
Fort Worth, TX	32.87	26.77	57.68	*2.16*	1.74	2.66	26.48
Atlanta, GA	26.20	15.38	31.22	*2.03*	1.50	2.75	38.02
San Jose, CA	28.00	25.10	50.04	*1.99*	1.37	2.90	6.59
Milwaukee, WI	27.09	20.78	40.01	*1.93*	1.56	2.39	27.44
Boston, MA	19.97	17.76	32.49	*1.83*	1.43	2.33	16.46
San Antonio, TX	38.11	24.46	44.47	*1.82*	1.44	2.29	13.76
Philadelphia, PA	24.34	18.66	33.74	*1.81*	1.60	2.05	86.50
Las Vegas, NV	17.75	16.90	30.33	*1.79*	1.30	2.48	7.83
Jacksonville, FL	36.54	31.71	56.32	*1.78*	1.52	2.07	40.13
Sacramento, CA	35.84	33.99	59.18	*1.74*	1.36	2.23	12.94
Virginia Beach, VA	17.21	16.12	26.92	*1.67*	1.15	2.42	4.96
Chicago, IL	27.35	20.09	33.11	*1.65*	1.49	1.83	126.37
Baltimore, MD	36.79	27.63	43.5	*1.57*	1.33	1.86	57.49
Cleveland, OH	35.42	34.49	36.43	1.06	0.87	1.28	4.35
Detroit, MI	32.54	33.44	29.45	0.88	0.71	1.09	−34.40

Nine cities were excluded from analyses: San Juan (no mortality data available); Honolulu CDP, Louisville/ Jefferson County, and Nashville/Davidson (data not at the city-level); Albuquerque, Colorado Springs, El Paso, Mesa and Tucson (fewer than 20 Black deaths)

[a]RRs in italics are statistically significant

Black/White Diabetes Mortality Rate Ratios and Annual Excess Black Deaths

Black/White diabetes mortality rate ratios (RRs) exceeded one in 40 of the 41 cities included in this analysis; 39 were statistically significant. RRs ranged from a low of 1.57 in Baltimore to a high of 3.78 in neighboring Washington, DC (Table 1). There were nearly 6,800 annual excess Black diabetes deaths in the USA during the study period (Table 1). City-level annual excess Black deaths ranged from 442 in New York City to none in Detroit (-34). The 41 cities included in this analysis represent 14 % of the US population. The annual number of excess Black diabetes deaths, however, in these cities represents 27 % of all excess Black diabetes deaths in the USA.

Ecological Factors

Variations, or lack thereof, in the 12 ecological factors examined at the city-level and along racial lines are informative. We briefly discuss these distributions here. Population size ranged from 350,000 in Wichita (RR=2.33) to 8.2 million in New York City (RR=2.92), and percent population Black ranged from 13.4 % in San Jose (RR=1.99) to 82.5 % in Detroit (RR=0.88) (Table 2). In all 41 cities, White household income was higher than Black household income, and in 38 of the cities was at least 1.5 times greater (Table 2). Similar differences were observed in the percent population living below the poverty line, with the percent Blacks living below the poverty line more than doubling the percent Whites in all but four cities examined (Detroit (1.1), Baltimore (1.8), Boston (1.9) and New York City (1.9)) (Table 2).

The Gini Index provides additional insight regarding the level of economic inequality in each city, not taking into account race. City-level Gini coefficients ranged from 0.395 to 0.576 (Table 2). Of the 41 cities included in analyses, 23 had higher Gini coefficients than the national coefficient of 0.465.[22] Finally, the index of isolation serves as a measure of segregation. White isolation values ranged from 31.9 % in Detroit to 80.5 % in Omaha, and Black isolation values ranged from 4.9 % in San Jose to 89.0 % in Detroit (Table 2). There were 18 cities that had high (>70 %) isolation values (Black, White, or Both), indicating high levels of segregation.[33]

Bivariate Correlation Analyses

Bivariate correlation analyses showed statistically significant associations at the 5 % significance level between Black/White diabetes mortality RRs and percent population Black, White MHHI, Black/White MHHI, percent White population living below the poverty line, and Black/White percent population living below the poverty line, and at the 10 % significance level, the Gini Index, Black and White IOIs (Table 3). While White poverty and White MHHI were both statistically significantly correlated with Black/White diabetes mortality RRs, neither Black poverty nor Black MHHI were correlated (Table 3). As White poverty increased, RRs decreased. RRs remained relatively flat, however, in relation to the magnitude of Black poverty. This means that the statistically significant correlation between the Black/White ratio of poverty and the disparity was driven largely by differences in the magnitude of White poverty (Table 3).

Black and White isolation indices were correlated at the 10 % significance levels, but in opposite directions. Analyses showed that the relationship between Black isolation and the diabetes mortality disparity was not linear. RRs were lower at the high end of the IOI values. Five of the cities with the lowest RRs (Philadelphia (RR= 1.81), Chicago (RR=1.65), Baltimore (RR=1.57), Cleveland (RR=1.06), and Detroit (RR=0.88)) had some of the highest Black isolation values, causing the

TABLE 2 Ecologic variables explored in the 50 most populous US cities (*N*=41)

US cities (in order of descending Black/White diabetes mortality rate ratio)	Population size	Percent White	Percent Black	MHHI White	MHHI Black	MHHI Black/White	Percent poverty White	Percent poverty Black	Percent poverty Black/White	IOI White	IOI Black	Gini index
United States	298 757 310	66.3	12.2	54189	33402	0.6	9.2	25.2	2.7	–	–	0.465
Washington, DC	585 267	31.4	55.0	53800	35018	0.7	8.4	25.4	3.0	63.28	79.98	0.543
San Francisco, CA	757 604	44.7	6.7	81269	27448	0.3	8.5	28.2	3.3	55.98	23.33	0.508
San Diego, CA	1 264 263	48.2	6.7	69760	38062	0.5	7.9	23.8	3.0	64.00	17.17	0.458
Omaha, NE	379 851	71.0	13.1	49172	24593	0.5	8.1	32.9	4.1	80.52	44.15	0.458
Seattle, WA	565 809	67.9	7.5	62697	28285	0.5	9.4	31.6	3.4	75.64	20.43	0.495
Phoenix, AZ	1 440 018	48.1	5.2	56351	32760	0.6	9.1	25.7	2.8	65.17	11.34	0.461
Dallas, TX	1 187 603	30.5	23.2	60916	28687	0.5	7.5	28.9	3.9	57.64	50.09	0.533
New York City, NY	8 246 310	35.1	23.7	64731	38818	0.6	11.2	21.1	1.9	65.16	60.39	0.535
Los Angeles, CA	3 770 590	29.3	9.7	65171	32183	0.5	9.4	24.7	2.6	56.71	33.07	0.524
Memphis, TN	649 443	30.2	62.3	49742	27888	0.6	9.4	31.5	3.4	60.59	79.44	0.501
Oakland, CA	372 247	24.7	30.4	70580	32527	0.5	7.8	24.4	3.1	49.18	41.15	0.504
Kansas City, MO	436 562	57.6	29.1	49879	27613	0.6	9.0	27.1	3.0	74.21	63.88	0.466
Oklahoma City, OK	540 321	60.7	13.9	46867	26902	0.6	10.7	29.6	2.8	68.31	42.72	0.473
Arlington, TX	356 764	48.4	17.3	58545	41223	0.7	7.0	17.3	2.5	57.58	23.61	0.413
Fresno, CA	471 722	34.0	7.9	49497	22682	0.5	11.9	36.9	3.1	47.00	14.30	0.459
Houston, TX	2 034 749	28.0	24.0	64092	29335	0.5	8.6	29.8	3.5	54.09	50.82	0.519
Tulsa, OK	384 040	62.4	15.9	43253	24229	0.6	11.0	31.5	2.9	69.64	45.67	0.504
Portland, OR	541 550	74.1	6.5	48994	25625	0.5	13.1	36.0	2.7	76.33	14.30	0.476
Indianapolis, IN	790 815	63.8	25.6	50377	31208	0.6	11.0	24.5	2.2	74.58	52.61	0.449
Denver, CO	576 842	50.5	9.7	52151	30705	0.6	11.1	26.4	2.4	66.48	27.74	0.504
Charlotte, NC	649 578	50.3	33.2	66786	35480	0.5	5.9	20.7	3.5	65.55	51.48	0.488
Wichita, KS	356 564	68.8	11.2	46704	26740	0.6	9.0	28.3	3.1	75.22	36.97	0.453
Austin, TX	725 306	49.9	8.3	50349	31246	0.6	11.5	28.8	2.5	62.92	19.95	0.483
Columbus, OH	724 095	63.3	26.1	46714	30879	0.7	15.1	32.4	2.1	72.39	51.64	0.436
Minneapolis, MN	362 513	63.3	17.6	50240	22924	0.5	11.5	39.7	3.5	74.15	34.60	0.496
Long Beach, CA	463 838	30.5	12.9	59457	34894	0.6	9.5	24.4	2.6	53.74	21.06	0.468

Fort Worth, TX	635 612	44.1	18.0	57067	29460	0.5	9.8	26.7	2.7	59.07	38.56	0.460
Atlanta, GA	439 275	35.7	56.4	80942	26677	0.3	6.9	33.6	4.9	72.49	80.76	0.576
San Jose, CA	898 901	31.7	3.1	85618	50705	0.6	6.4	13.4	2.1	47.20	4.94	0.433
Milwaukee, WI	584 007	40.9	38.4	44598	25600	0.6	12.6	37.1	2.9	65.51	70.74	0.436
Boston, MA	600 980	50.0	22.2	62605	33702	0.5	13.0	24.9	1.9	69.21	52.81	0.530
San Antonio, TX	1 267 984	29.3	6.3	56514	33586	0.6	9.2	22.8	2.5	44.57	18.39	0.460
Philadelphia, PA	1 454 382	39.4	43.0	45967	28319	0.6	13.1	30.4	2.3	68.95	74.02	0.487
Las Vegas, NV	558 892	51.8	10.4	61672	32721	0.5	7.4	23.2	3.1	59.86	19.92	0.452
Jacksonville, FL	797 966	58.7	29.9	53800	33951	0.6	7.9	22.8	2.9	67.88	53.36	0.442
Sacramento, CA	446 721	38.3	14.2	50601	33399	0.7	12.3	25.7	2.1	48.50	20.37	0.435
Virginia Beach, VA	436 903	67.1	19.0	62733	45604	0.7	4.7	12.2	2.6	71.10	29.11	0.395
Chicago, IL	2 740 224	30.9	34.7	50377	30417	0.6	9.4	32.1	3.4	61.47	82.08	0.509
Baltimore, MD	639 493	30.4	63.6	51707	30531	0.6	13.5	24.5	1.8	61.95	83.00	0.490
Cleveland, OH	405 014	35.8	52.5	34288	21465	0.6	17.5	36.5	2.1	64.58	80.56	0.467
Detroit, MI	837 711	8.4	82.5	29515	28836	1.0	30.7	32.8	1.1	31.86	88.96	0.473

Nine cities were excluded from analyses: San Juan (no mortality data available); Honolulu CDP, Louisville/Jefferson County, and Nashville/Davidson (data not at the city-level); Albuquerque, Colorado Springs, El Paso, Mesa, and Tucson (fewer than 20 Black deaths)

TABLE 3 Correlations between ecologic variables and Black/White diabetes mortality rate ratios, 2005–2007 (*N*=41)

Ecologic variables	Correlation coefficient	*P* value
Population size[a]	0.0333	0.8364
Percent population White[b]	0.2348	0.1395
Percent population Black[a]	-0.3323	0.0338
White median household income[b]	0.3723	0.0165
Black median household income[a]	-0.0460	0.7752
Black/White median household income[a]	-0.4554	0.0028
Percent White living below the poverty line[a]	-0.3260	0.0375
Percent Black living below the poverty line[b]	-0.0235	0.8842
Black/White percent living below the poverty line[b]	0.4526	0.0030
Gini index[b]	0.2704	0.0873
Index of isolation (White)[b]	0.2672	0.0913
Index of isolation (Black)[a]	-0.2606	0.0999

Nine cities were excluded from analyses: San Juan (no mortality data available); Honolulu CDP, Louisville/Jefferson County, and Nashville/Davidson (data not at the city-level); Albuquerque, Colorado Springs, El Paso, Mesa, and Tucson (fewer than 20 Black deaths)

[a]Spearman Rank correlation coefficient calculated due to violation of normality assumption

[b]Pearson's correlation coefficients calculated (data were linear and normally distributed)

association to decrease with increased Black isolation. Conversely, in general, RRs increased as White isolation increased.

Multivariate Analyses

Multivariate analyses showed that adjusting for segregation alone, measured by the index of isolation for Whites and Blacks, explained 12.3 % of the disparity (Table 4: Model II). Adjusting for race-specific MHHI or race-specific percent of the population living below the poverty line (measures of racial economic inequality) explained 53.3 and 58.5 % of the disparity, respectively (Table 4, Models III and IV). Adjusting for race-specific MHHI and race-specific IOI explained 69.2 % of the disparity (Table 4: Model V), and the final model (Table 4: Model VI), adjusting for both race-specific percent population living below the poverty line and race-specific IOI, explained 72.6 % of the disparity. The final model reduced the disparity for the 41 cities included in the analysis from 2.17 (95 % CI: 1.97–2.38) to 1.32 (95 % CI: 1.07–1.63). The RRs obtained from the multivariate models were based on data for the 41 cities included in the analysis, thus the unadjusted RR of 2.17 is different than the US RR of 2.13.

DISCUSSION

This study confirms that Blacks are dying at a higher rate from diabetes than Whites in virtually every major city in the nation and indicates that the largest cities bear a disproportionate burden of this disparity. It also shows that there is significant variation in the magnitude of the disparity across cities. The national Black/White diabetes mortality RR, showing that Blacks are at more than two times greater risk of mortality than Whites, is an average.[5,8] Examining local data allows us to obtain

TABLE 4 Relationship between race and diabetes mortality rate before (Model I) and after adjustment for potential explanatory ecologic variables (Models II–VI)

Negative binomial regression models Outcome—deaths due to diabetes by city (N=41 cities, 21,914 deaths over 3 years)	NHB/NHW diabetes mortality rate ratio (95 % CI)	Percent of disparity explained (%)
I. Unadjusted	2.17 (1.97–2.38)	–
Adjusted for:		
II. Index of isolation (by race)	2.02 (1.80–2.27)	12.3
III. Median household income (by race)	1.54 (1.22–1.95)	53.3
IV. Percent living below poverty line (by race)	1.48 (1.21–1.82)	58.5
V. Median household income (by race) Index of isolation (by race)	1.36 (1.11–1.67)	69.2
VI. Percent living below poverty line (by race) Index of isolation (by race)	1.32 (1.07–1.63)	72.6

Nine cities were excluded from analyses: San Juan (no mortality data available); Honolulu CDP, Louisville/Jefferson County, and Nashville/Davidson (data not at the city-level); Albuquerque, Colorado Springs, El Paso, Mesa, and Tucson (fewer than 20 Black deaths)

additional insight into which cities are most affected and what those cities have or do not have in common.

In multivariate analyses racial economic inequality had the greatest impact on the disparity, followed by segregation. By adjusting for the ratio of Black/White poverty and the indices of isolation, nearly three quarters of the observed disparity was explained. While many studies have reported an association between poverty and diabetes-related racial disparities, this study has shown that it is not just poverty that matters, but rather the level of economic inequality that exists between races.[10,11]

Economic inequality had a greater impact on the disparity in diabetes mortality than segregation. A prior study investigating disparities in breast cancer mortality in the 25 most populous US cities showed that segregation and MHHI were both statistically significantly correlated with Black/White breast cancer mortality RRs and that the correlations were of similar magnitude.[28] Diabetes is a chronic disease that can be well controlled given the proper resources, whereas breast cancer survival is more dependent on timing of diagnosis and treatment initiation. This is one possible reason for the differences observed between the two studies. This brings to question whether context specific factors such as economic inequality and segregation behave similarly across causes of mortality, and specifically whether there are differences between deaths due to chronic vs. acute disease.

The smallest disparities in diabetes mortality were observed in cities that we might have expected to have the largest due to high levels of Black isolation (Detroit, Cleveland, Baltimore, Chicago, and Philadelphia). Detroit is an outlier in many ways. Blacks are not a minority group in this city (% population NHB= 82.5 %). Additionally, a similarly large percentage of Whites and Blacks in Detroit live below the poverty line, so there is no evidence of racial economic inequality. In Detroit, diabetes mortality rates among Blacks and Whites are equally high, but the city has one of the lowest Black rates and one of the highest White rates of the 41 cities studied. The low RR seems to be largely driven by the high White mortality rate. Both rates exceed the national rate and intervention is needed overall.

The RRs observed in Cleveland, Baltimore, Chicago, and Philadelphia were lower than expected, given that all had Black isolation values in the highest quintile and all were greater than 70 %, indicating that these cities are highly segregated. In general, as Black isolation increased, so did RRs. These four cities seemed to be exceptions. Like Detroit, the low RR in Cleveland can be partially explained by the high White mortality rate (the highest in the study). This is not true for Baltimore, Chicago, or Philadelphia. Unlike Detroit, however, the Black rate in Cleveland is not one the lowest, and despite overall economic hardship there is still significant economic inequality. When these five cities were removed from analyses (data not shown), high values of isolation were no longer correlated with a decrease in the disparity.

Although the comparatively low RRs in these cities seemed counterintuitive, other studies have observed similar phenomenon.[4,37–40] While health measures among Blacks consistently remain worse than among Whites, some studies have shown that low-income Blacks living in hypersegregated areas have better health outcomes than low-income Blacks living in less segregated areas, leading to smaller differences between Blacks and Whites in areas that are highly segregated.[4,37–40] It is hypothesized that in highly segregated areas, there are more targeted interventions and improved access to care through safety net providers for minority, low-income populations.[4,38–40] Additionally, there is evidence that increases in community resources and social support services in these areas may improve access to culturally appropriate and better quality care, which may help counteract the detrimental effects of segregation and discrimination.[37,40,41] In some cases, people living in hypersegregated neighborhoods have reported less perceived discrimination than those living in more diverse neighborhoods, which may lead to fewer delays in seeking and receiving care.[40] Finally, some studies have hypothesized that hypersegregated low-income areas may attract better qualified physicians who are passionate about urban, minority health, improving the quality of care received at safety net hospitals and health centers compared to less segregated, low-income areas.[4,37,40] Overwhelmingly, studies have shown the impact of segregation to be devastating for health, social and economic outcomes.[40,42–44] It is possible that as a result, some large, higher profile cities that are hypersegregated have received greater attention and funding to address some of these issues and some of it may be working.

METHODOLOGICAL CONSIDERATIONS

The data for these analyses come from two robust sources, national death certificate files and the census bureau. Both sources of data provide large sample sizes, even after stratification. Although we have analyzed data over a 3-year period in attempt to make our calculations as stable as possible, these rates, and thus the disparity, can and will vary over time. City-level rates cannot be viewed as fixed and should instead be understood in the larger context.

While national data sets allowed for comparison of mortality rate ratios across cities throughout the USA, we were unable to control for physician coding practices. If there were systematic differences by race or geographic area this could impact the results of this study. The racial disparity in diabetes mortality was, however, consistently observed in almost every major US city.

While we have only presented comparisons of Blacks and Whites in this study, when addressing disparities at the local level, rates should be calculated for all major race/ethnicity categories (e.g., Mexicans, Puerto Ricans, Asians, Native Americans) to truly understand the context in which one is working. This may require a longer period of evaluation due to smaller numbers of deaths.

Finally, this study is limited in scope as there are not a wide variety of data available at the city-level that would allow us to exploit what underlying factors, resulting from racial economic inequality and segregation, are more directly causing the observed disparities. Thus, we are only able to speculate what local level issues are at play and make an appeal for local level research.

CONCLUSIONS

This paper has generated mortality rates for non-Hispanic Black and non-Hispanic White people in 41 of the 50 most populous US cities and used the ratio of these rates as a measure of racial disparities in diabetes mortality. We have sought ecological city-level predictors of the racial disparities in these cities and found five of the 12 that were examined to be statistically significant. Nearly 75 % of the disparity was explained by economic inequality and segregation in multivariate analyses. These variables may be seen as "fundamental causes" of disease.[45] There are opportunities within this context to employ evidence-based interventions to improve diabetes outcomes and limit diabetes mortality.

This study provides three important insights. First, Black/White economic inequalities, rather than poverty alone, are fueling disparities in diabetes mortality along racial lines in the USA, and segregation still matters. As segregation increases, so does the disparity, with a few exceptions observed in some of the larger, hypersegregated cities. Second, the magnitude of the disparity in diabetes mortality and the influences of racial economic inequality and segregation vary widely by city. Research must be conducted at the local level to understand context specific barriers to eliminating disparities in diabetes mortality, providing essential insights into how to best intervene.[21] Third, the experiences of cities like Baltimore, Chicago, Cleveland, and Philadelphia, that have surprisingly low diabetes mortality disparities, may offer lessons on how we can improve diabetes management even in the face egregious inequalities.

At a time when diabetes should be a chronic disease not a death sentence, there are nearly 6,800 excess deaths associated with the disease among Blacks every year. Understanding the complex roles of segregation and racial economic inequality, and the importance of local data are vital to eliminating disparities in diabetes mortality at the city-level and throughout the USA. Despite the barriers imposed by these ecological variables, there is much that can and must be done to make matters better today.

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