Organizing CDC Census Tract Health Data into City Council Districts to Better Understand Drivers of Health Inequality in Richmond, Virginia

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Class of 2019

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Abstract: The Centers for Disease Control 500 Cities Project provides a wealth of data related to health behaviors, use of preventive services, and health outcomes for the 500 largest cities in the United States. These data are made available at the census tract level within these cities. While census tract-level data lends itself well to mapping neighborhoods or entire cities, it would be more useful to aggregate the data into boundaries which have political representation. For this project, geolocation data for the census tracts within Richmond, Virginia were used to organize the health information into respective city council districts. We found significant health disparities among city council districts, highlighted by a 13 year gap in life expectancy between west Richmond's district 1 (82.24 years) and east Richmond's 6th district (69.20 years). More broad patterns showed better health by objective and subjective measures in the western districts and poorer health in the eastern and southern districts of the city. Strong district level disparities were also seen in health behaviors and in utilization of preventive services among people >65 years old. Community-level health data organized into politically represented entities may be leveraged to create and implement collaborative public health initiatives.

1. Introduction

The stated purpose of the Centers for Disease Control 500 Cities: Local Data for Better Health project is to allow stakeholders to help develop and implement targeted prevention activities, identify emerging health problems, and establish and monitor key health objectives in order to develop effective interventions [1]. It includes 27 health factors and outcomes at the census tract level for each of the 500 largest American cities. These measures are broadly organized into three categories: health behaviors, use of preventive services, and health outcomes.

Big data is now impacting the way public health information is utilized and is helping establish the nascent field of precision public health [2]. The 500 Cities project and other smaller scale data initiatives have enabled community-level public health studies to greatly expand in recent years. Targeting public health initiatives to increasingly specific communities may lead to improved results, as we understand that personalization is critical for behavior change on the individual level [3, 4].

City level public health data may be ideal for local health departments, who often oversee health of an entire city. However, cities are typically governed by a council of officials elected to represent their district, thus city council districts are the level at which city residents are politically represented [5, 6]. Therefore, it may be useful to organize public health data at the city council district level if it is going to be leveraged into meaningful change.

Richmond, Virginia is governed by an elected council-mayor form of government with the mayor serving as city manager while the council serves as the legislative branch. In Richmond the city is divided into 9 council districts, each of which have an elected councilperson to represent their interests. Currently, the city is represented by Andreas Addison, Kimberly Gray, Chris Hilbert, Kristen Larson, Parker Agelasto, Ellen Robertson, Cynthia Newbille, Reva Trammell, and Michael Jones who represent the 1st through 9th districts, respectively.

In Richmond at the individual neighborhood level there is a 20-year gap in life expectancy between the respective highest and lowest neighborhoods [7]. However, the local data have never been aggregated with the level of information provided by the CDC 500 Cities Project, nor have they been organized into politically represented jurisdictions.

In this study, health data from the CDC 500 Cities Project was organized into the city council districts of Richmond, Virginia in order to assess for health disparities and their respective drivers among jurisdictions represented politically in the city government [8]. Using geolocation data from each of the census tracts in Richmond, we obtained council district level data on the use of preventive services (including lack of health insurance among adults, past year routine checkups with primary care provider, past year visits to dentist, taking medicine for hypertension among adults with diagnosed hypertension, cholesterol screening, mammography use, PAP tests among women, colorectal cancer screening among adults 50-75 years old, up to date core preventive services for men and women >65 years old), unhealthy behaviors (including percentages of: smoking, sedentary lifestyle, obesity, sleeping less than 7 hours per night, and binge drinking), and health outcomes (including percentages of: arthritis, asthma, cancer (excluding skin cancer), hypertension, hyperlipidemia, diabetes, chronic kidney disease, chronic obstructive pulmonary disease, coronary heart disease, stroke, subjective reporting of physical and mental health not being good for 2 weeks of the last month, and missing all teeth among those aged >65 years old). In addition to the data provided from the CDC 500 Cities Project, the geolocations were also used to determine the walk and bike scores as generated by the website Walk Score [9].

2. Methods

Through the 2018 release of the CDC's 500 Cities Project we obtained census tract level data with 27 markers pertaining to use of preventive services, unhealthy behaviors, and health outcomes for Richmond, Virginia. The datasets used include year 2015 and 2016 model-based small area estimates for the chronic disease measures detailed above [1]. The data were provided by the CDC Division of Population Health, Epidemiology and Surveillance Branch and the project was co-funded by the Robert Wood Johnson Foundation and the CDC Foundation [1]. Sources of data for this initiative include Behavioral Risk Factor Surveillance System (BRFSS) data (years 2015-2016), Census Bureau 2010 census population data, and American Community Survey (ACS) 2012-2016 and 2011-2015 estimates [1].

Google Maps was utilized to find the closest corresponding address to the center of the census tract, allowing assignment of the associated health data to one of nine city council districts [8]. Additionally, measures of walkability and bikeability were generated by the website Walk Score for the corresponding addresses. The Walk Score methodology was developed with the Walk Score advisory board and has been validated by leading academic researchers [9]. Walk Score measures the walkability of any address using a patented system. For each address, Walk Score analyzes hundreds of walking routes to nearby amenities with points awarded based on the distance to amenities in each category. Amenities within a 5 minute walk (.25 miles) are given maximum points with a point function used to give points to more

distant amenities up to a 30 minute walk [9]. Walk Score also measures pedestrian friendliness by analyzing population density and road metrics such as block length and intersection density. Data sources for Walk Score include Google, Education.com, Open Street Map, U.S. Census, Localeze, and user generated places [9]. The Bike Score measures whether a location is accommodating for bike recreation and transportation on a scale from 0 - 100 based on bike lanes, hills, destinations, road connectivity, and share of bike commuters, each given equal weight [9].

An Excel workbook was used to organize the data. Citywide averages for the 27 health markers were established by averaging the data based on the weighted population of the individual census tract, which vary based on migration over time. Correlation coefficients between the health markers were calculated based on the Pearson product-moment coefficient within Excel. Correlation coefficients determine how well a set of objective measures from two variables support a hypothesis that the variables are linearly related to one another [10]. Coefficients were calculated for both preventive services and health behavior versus health outcomes, respectively.

Figures and tables were generated using Excel and PowerPoint platforms. Color gradients were established based on conditional formatting within Excel and the colors generated were then translated into RGB (Red-green-blue) codes from the website Color Code Picker. These codes were then used as fill colors for the council district maps.

3. Results

Among city council districts in Richmond, Virginia there is a 13.04 year gap between the highest and lowest life expectancies. The three districts highest for life expectancy are district 1 (82.24 years), district 2 (80.50), and district 4 (78.67), while the three lowest districts are district 8 (73.98), district 7 (70.71), and district 6 (69.20) (Figure 1). The average life expectancy citywide was 75.36 years, compared to a United States average of 78.60 [11].

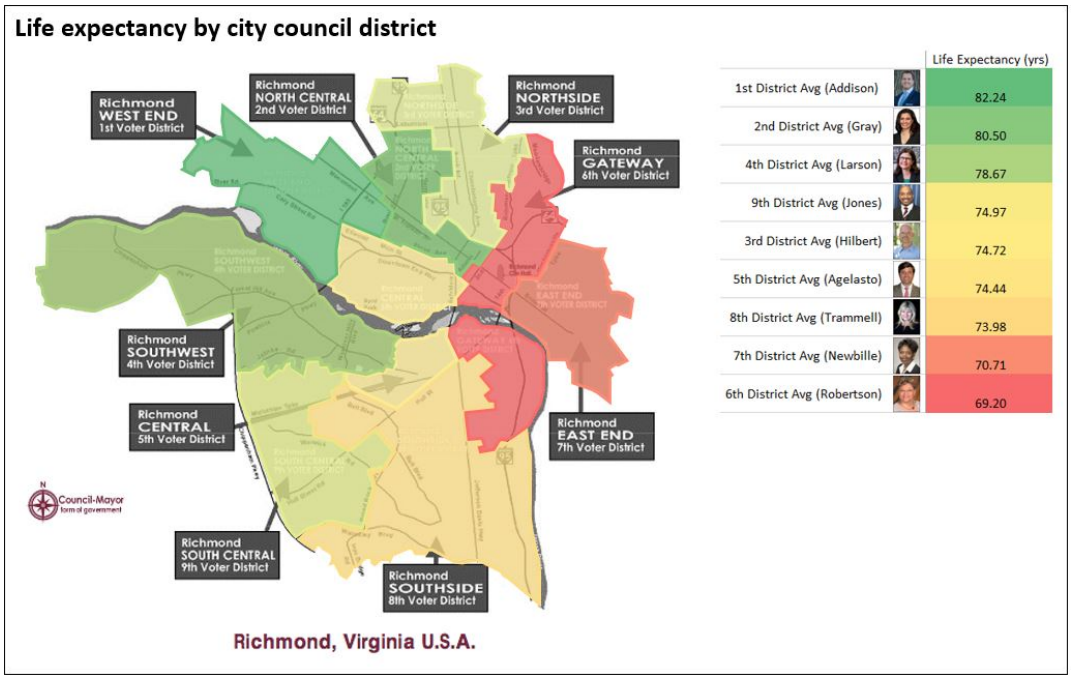

Figure 1. Life expectancy in Richmond, Virginia organized by city council district.

Health Outcomes: Similar disparities were seen regarding the prevalence of various other health outcomes including asthma, hypertension, hyperlipidemia, and diabetes mellitus for which council district maps were created (figures 2-5). These outcomes showed gaps between low and high districts of 3.82%, 10.76%, 22.6%, and 14.9%, respectively. As well as additional health outcomes including arthritis, cancer (excluding skin cancer), coronary heart disease (CHD), chronic obstructive pulmonary disease (COPD), chronic kidney disease (CKD), stroke, and edentulous >65 years old which are organized in color graded tables (tables 1-7).

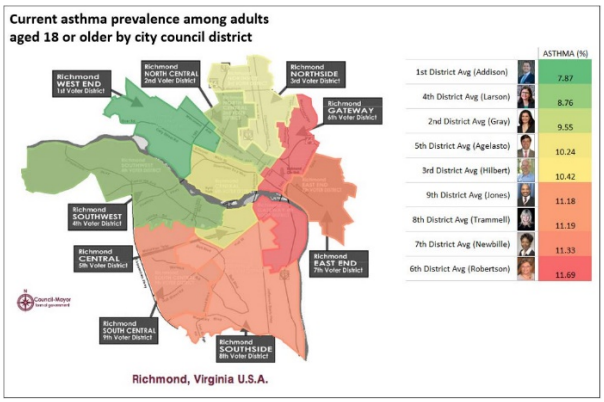

Figure 2. Asthma organized by district

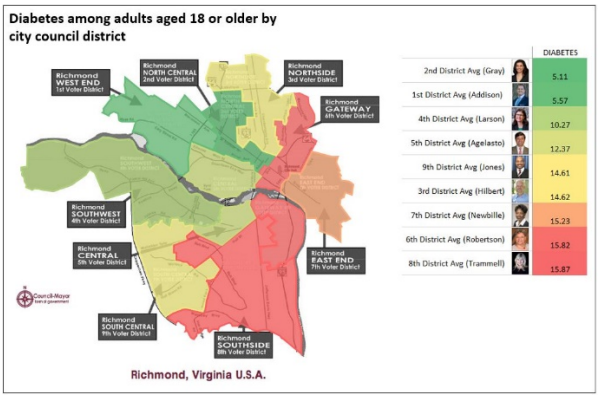

Figure 3. Diabetes organized by district

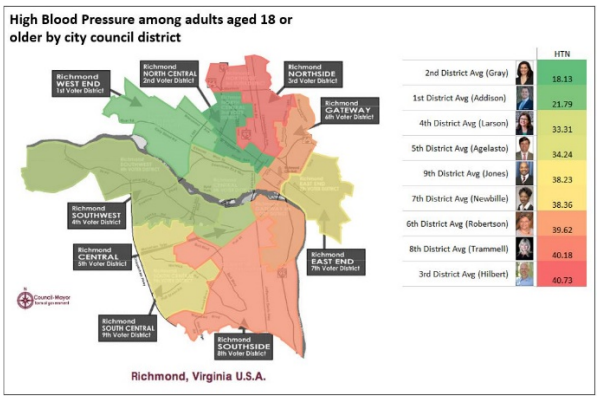

Figure 4. High blood pressure by district

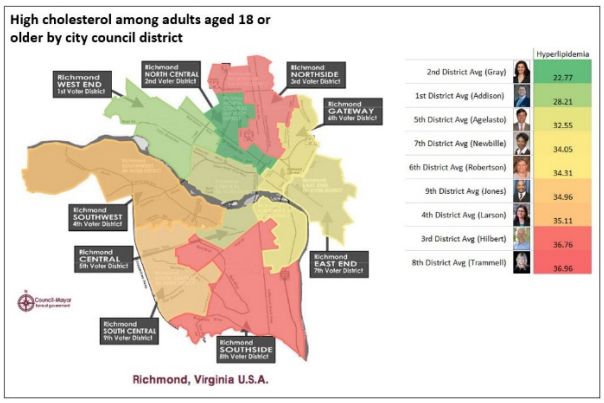

Figure 5. High Cholesterol by district

	ARTHRITIS
2nd District Avg (Gray)	11.91
1st District Avg (Addison)	16.73
5th District Avg (Agelasto)	22.06
6th District Avg (Robertson)	24.21
4th District Avg (Larson)	24.59
7th District Avg (Newbille)	24.82
9th District Avg (Jones)	24.82
8th District Avg (Trammell)	25.61
3rd District Avg (Hilbert)	27.26

	CANCER
2nd District Avg (Gray)	2.88
6th District Avg (Robertson)	4.22
7th District Avg (Newbille)	4.68
5th District Avg (Agelasto)	4.72
9th District Avg (Jones)	4.76
8th District Avg (Trammell)	4.76
1st District Avg (Addison)	5.34
3rd District Avg (Hilbert)	6.50
4th District Avg (Larson)	6.87

	Coronary Heart Dz
2nd District Avg (Gray)	2.89
1st District Avg (Addison)	3.69
5th District Avg (Agelasto)	5.62
4th District Avg (Larson)	5.95
9th District Avg (Jones)	6.37
7th District Avg (Newbille)	6.49
6th District Avg (Robertson)	6.57
3rd District Avg (Hilbert)	7.06
8th District Avg (Trammell)	7.18

	CKD
2nd District Avg (Gray)	1.71
1st District Avg (Addison)	1.81
4th District Avg (Larson)	2.83
5th District Avg (Agelasto)	3.19
9th District Avg (Jones)	3.60
3rd District Avg (Hilbert)	3.71
7th District Avg (Newbille)	3.77
8th District Avg (Trammell)	3.82
6th District Avg (Robertson)	3.82

	COPD
2nd District Avg (Gray)	4.02
1st District Avg (Addison)	3.62
5th District Avg (Agelasto)	6.44
4th District Avg (Larson)	5.69
9th District Avg (Jones)	7.88
7th District Avg (Newbille)	7.99
6th District Avg (Robertson)	8.28
3rd District Avg (Hilbert)	7.27
8th District Avg (Trammell)	8.52

	STROKE
2nd District Avg (Gray)	1.58
1st District Avg (Addison)	1.64
4th District Avg (Larson)	3.07
5th District Avg (Agelasto)	3.94
9th District Avg (Jones)	4.50
3rd District Avg (Hilbert)	4.74
7th District Avg (Newbille)	5.04
8th District Avg (Trammell)	4.99
6th District Avg (Robertson)	5.22

	TEETHLOST >65
2nd District Avg (Gray)	15.82
1st District Avg (Addison)	7.04
4th District Avg (Larson)	11.38
5th District Avg (Agelasto)	20.08
9th District Avg (Jones)	25.18
3rd District Avg (Hilbert)	19.73
7th District Avg (Newbille)	25.62
8th District Avg (Trammell)	28.81
6th District Avg (Robertson)	29.24

Tables 1-7. Arthritis, Cancer (excluding skin), Coronary heart disease, Chronic kidney disease, COPD, Stroke, and all teeth missing >65 years old all organized by district

Health Behaviors: Differences in health behaviors also varied widely among city council districts. Health behaviors mapped include smoking, obesity, sedentary lifestyle, and sleeping less than 7 hours per night (figures 6-9). These behaviors showed gaps between high and low districts of 14.8%, 18.96%, 22.41%, and 14.69%, respectively. The final health behavior data for binge drinking was not included.

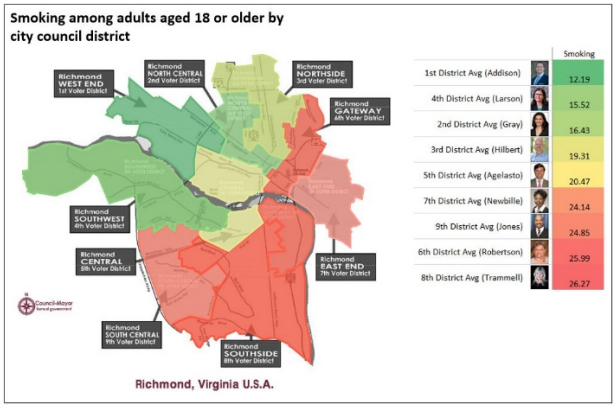

Figure 6. Smoking organized by district

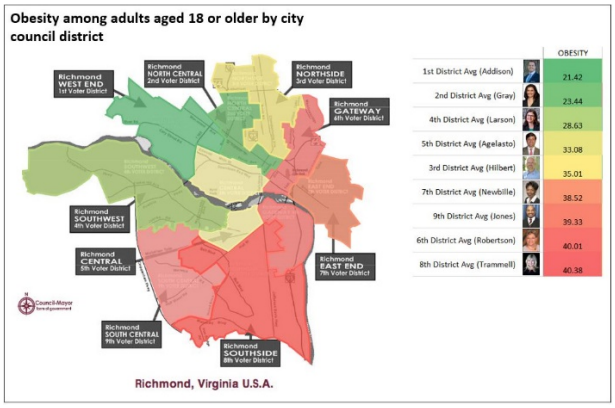

Figure 7. Obesity by district

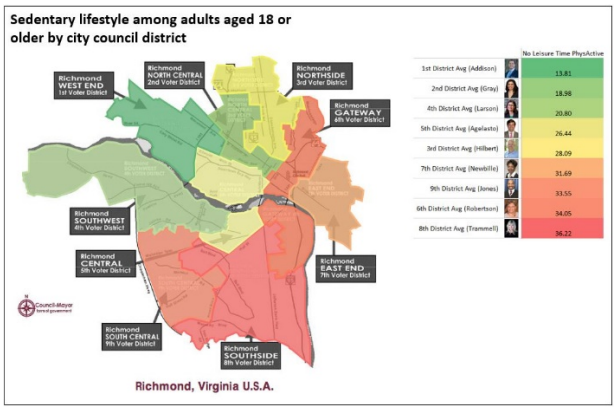

Figure 8. Sedentary lifestyle by district

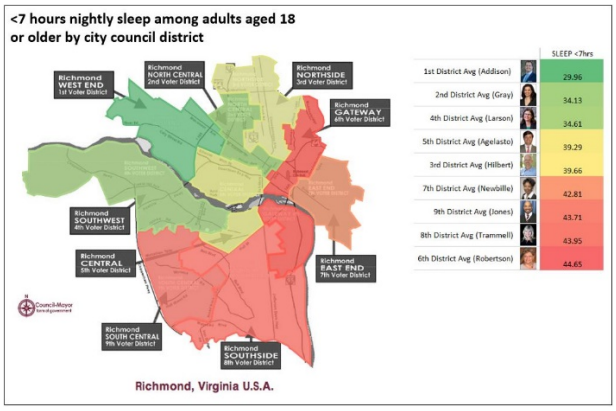

Figure 9. Lack of sleep by district

Preventive Services: Access and engagement with preventive services also varied among districts. The mapped factors include lack of insurance (prior to Virginia Medicaid expansion in 2019), percentages of male and female 65 year olds having all age-recommended core preventive services as well as the addition here of the walk and bike scores (figures 10-14). Non-mapped preventive factors include taking

blood pressure medications, primary care visit within last year, lipid screen, colorectal cancer screen, dental visit within last year, mammogram, and PAP test (tables 8-14).

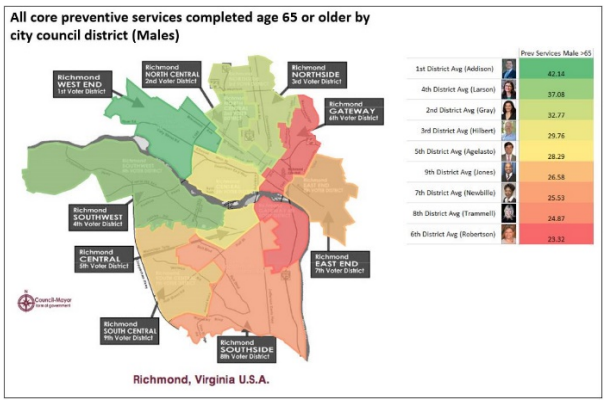

Figure 10. All preventive services >65 years male

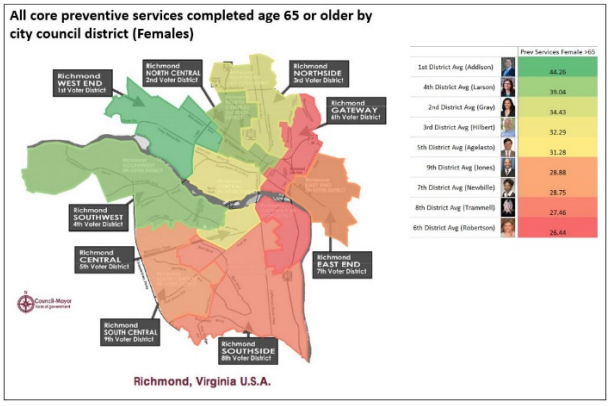

Figure 11. All preventive services >65 years female

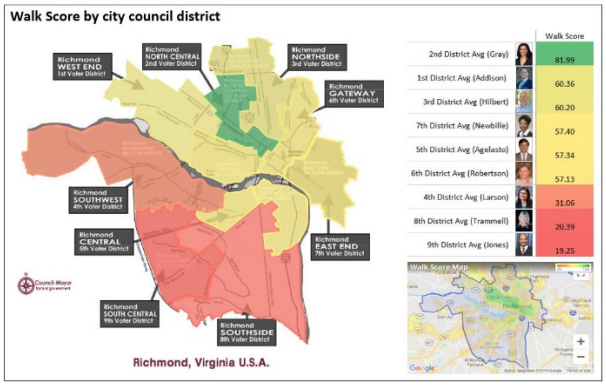

Figure 12. Walk score by district

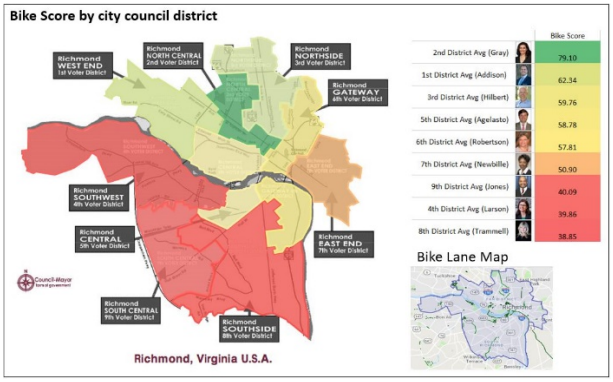

Figure 13. Bike score by district

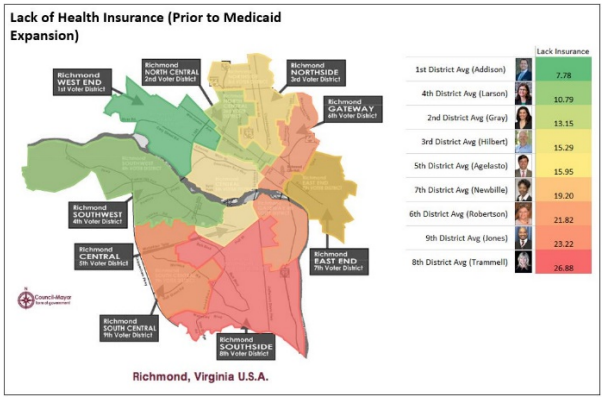

Figure 14. Lack of health insurance by district

	Taking BPMED
3rd District Avg (Hilbert)	81.62
4th District Avg (Larson)	79.92
8th District Avg (Trammell)	77.89
9th District Avg (Jones)	77.82
7th District Avg (Newbille)	77.17
6th District Avg (Robertson)	75.93
5th District Avg (Agelasto)	75.46
1st District Avg (Addison)	71.99
2nd District Avg (Gray)	59.40

Table 8. BP meds by district

	Dr CHECKUP w/in year
3rd District Avg (Hilbert)	78.22
4th District Avg (Larson)	75.34
6th District Avg (Robertson)	75.08
7th District Avg (Newbille)	74.93
9th District Avg (Jones)	74.87
8th District Avg (Trammell)	73.88
5th District Avg (Agelasto)	73.15
1st District Avg (Addison)	69.89
2nd District Avg (Gray)	66.96

Table 9. PCP visit last year by district

	CHOL SCREEN
4th District Avg (Larson)	82.04
3rd District Avg (Hilbert)	77.68
1st District Avg (Addison)	76.97
7th District Avg (Newbille)	72.13
9th District Avg (Jones)	70.94
5th District Avg (Agelasto)	70.37
8th District Avg (Trammell)	69.02
6th District Avg (Robertson)	67.25
2nd District Avg (Gray)	58.50

Table 10. Lipid screen by district

	COLON_SCREEN
1st District Avg (Addison)	73.58
4th District Avg (Larson)	69.65
2nd District Avg (Gray)	64.77
3rd District Avg (Hilbert)	64.45
5th District Avg (Agelasto)	62.84
7th District Avg (Newbille)	59.17
9th District Avg (Jones)	58.00
6th District Avg (Robertson)	55.86
8th District Avg (Trammell)	55.46

Table 11. CRC screen by district

	DENTAL Care
1st District Avg (Addison)	80.40
4th District Avg (Larson)	73.22
2nd District Avg (Gray)	66.71
3rd District Avg (Hilbert)	62.96
5th District Avg (Agelasto)	61.37
7th District Avg (Newbille)	54.36
9th District Avg (Jones)	52.25
6th District Avg (Robertson)	49.77
8th District Avg (Trammell)	48.77

Table 12. Dental visit by district

	MAMMOGRAM
7th District Avg (Newbille)	84.88
6th District Avg (Robertson)	84.77
3rd District Avg (Hilbert)	84.74
5th District Avg (Agelasto)	84.56
9th District Avg (Jones)	83.94
4th District Avg (Larson)	83.43
8th District Avg (Trammell)	83.34
1st District Avg (Addison)	83.21
2nd District Avg (Gray)	83.15

Table 13. Mammogram by district

	PAPTEST
4th District Avg (Larson)	85.21
3rd District Avg (Hilbert)	85.06
1st District Avg (Addison)	84.49
7th District Avg (Newbille)	84.30
9th District Avg (Jones)	83.77
8th District Avg (Trammell)	83.29
5th District Avg (Agelasto)	83.16
6th District Avg (Robertson)	82.83
2nd District Avg (Gray)	77.98

Table 14. PAP test by district

Subjective measures of health: the final factors include subjective measures of mental and physical health. Those surveyed responded weather they felt mentally unhealthy for 2 weeks out of the last month and weather they felt physically unhealthy for 2 weeks of the last month. The results are mapped by council district with wide disparity with mental and physical health gaps of 7.25% and 9.71% between subjectively healthiest and least healthy districts, respectively (figures 15-16).

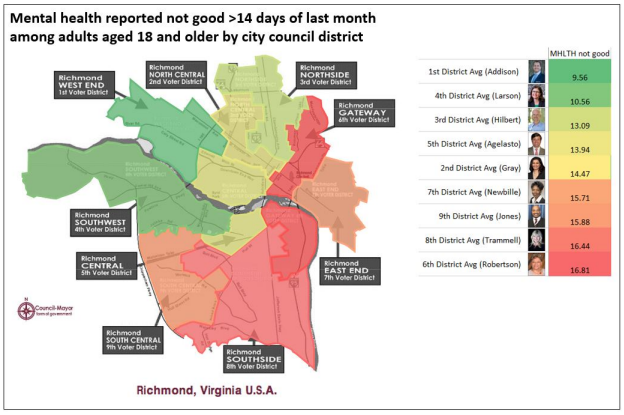

Figure 15. Mental health not good by district

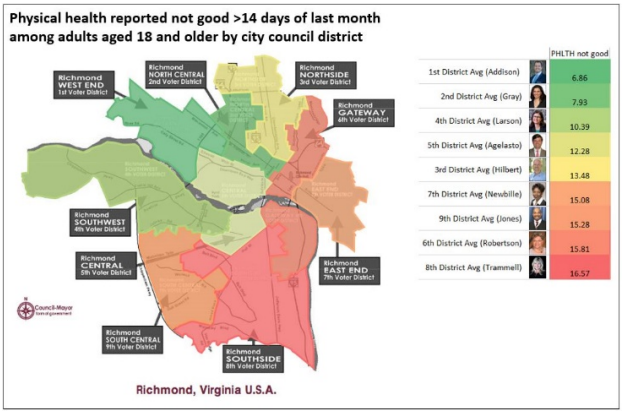

Figure 16. Physical health not good by district

Final analysis included comparing both preventive services and health behaviors versus health outcomes to determine how related each factor is to the respective health outcome (tables 15-16). Additionally, each preventive service and health behavior were individually plotted against life expectancy (table 17). Life expectancy was highly negatively correlated with smoking, obesity, sedentary lifestyle, and poor sleep as well as lacking insurance and was strongly positively correlated with colorectal cancer screening, getting all core preventive services for those >65 years old, and with dental appointments.

Preventive Factors vs Health Outcomes Correlation														
	Life Expectancy	Arthritis	HTN	Cancer	Asthma	Coronary Heart Dz	COPD	Diabetes	Hyperlipidemia	Chronic Kidney Dz	MHLTH poor 14d/month	PHLTH poor 14d/month	Stroke	All Teeth Lost >65yo
Lack Ins	-0.72	0.53	0.68	-0.43	0.89	0.66	0.88	0.79	0.55	0.78	0.94	0.92	0.80	0.95
Taking BP Rx	-0.35	0.91	0.81	0.68	0.33	0.81	0.53	0.68	0.90	0.68	0.13	0.49	0.62	0.29
PCP Apt Last Yr	-0.50	0.91	0.88	0.50	0.52	0.84	0.63	0.78	0.85	0.77	0.30	0.60	0.74	0.44
Lipid Screen	0.47	0.11	-0.12	0.86	-0.64	-0.07	-0.45	-0.30	0.12	-0.29	-0.78	-0.51	-0.35	-0.68
Colon CA Screen	0.78	-0.53	-0.69	0.47	-0.94	-0.66	-0.90	-0.81	-0.51	-0.81	-0.98	-0.93	-0.84	-0.98
All Core Prev Male >65yo	0.85	-0.61	-0.80	0.41	-0.95	-0.71	-0.89	-0.88	-0.57	-0.86	-0.93	-0.92	-0.88	-0.95
All Core Prev Female >65yo	0.83	-0.62	-0.79	0.39	-0.95	-0.72	-0.90	-0.88	-0.57	-0.87	-0.94	-0.93	-0.89	-0.96
Dental Apt Last Yr	0.81	-0.61	-0.77	0.41	-0.97	-0.73	-0.94	-0.88	-0.59	-0.87	-0.98	-0.97	-0.89	-0.99
Mammogram	-0.34	0.14	0.27	-0.15	0.26	0.09	0.11	0.27	0.03	0.23	0.13	0.13	0.24	0.16
PAP Test	0.25	0.15	-0.01	0.65	-0.42	-0.03	-0.31	-0.16	0.13	-0.15	-0.57	-0.34	-0.20	-0.47
Walk Score	0.05	-0.39	-0.33	-0.28	-0.18	-0.33	-0.27	-0.26	-0.46	-0.27	-0.15	-0.28	-0.21	-0.20

Table 15. Preventive service correlations to health outcomes

Health Behaviors vs Health Outcomes Correlations														
	Life Expectancy	Arthritis	HTN	Cancer	Asthma	Coronary Heart Dz	COPD	Diabetes	Hyperlipidemia	Chronic Kidney Dz	MHLTH poor 14d/month	PHLTH poor 14d/month	Stroke	All Teeth Lost >65yo
Smoking	-0.80	0.58	0.74	-0.44	0.96	0.70	0.93	0.85	0.56	0.84	0.98	0.96	0.87	0.99
Sedentary	-0.80	0.74	0.86	-0.25	0.96	0.83	0.98	0.94	0.72	0.94	0.94	0.99	0.95	0.98
Obesity	-0.84	0.76	0.89	-0.24	0.96	0.83	0.96	0.96	0.72	0.94	0.90	0.98	0.95	0.95
<7hrs Sleep	-0.85	0.66	0.83	-0.37	0.96	0.75	0.92	0.92	0.62	0.89	0.93	0.95	0.91	0.95

Table 16. Health behavior correlations to health outcomes

Life Expectancy Correlations														
	Smoking	Sedentary	Obesity	<7hrs Sleep	Lack Ins	Taking BP Rx	PCP Apt	Lipid Screen	Colon CA Screen	All Core Prev Male	All Core Prev Female	Dental Apt	Mammogram	PAP Test	Walk Score
r to Life Expectancy	-0.80	-0.80	-0.84	-0.85	-0.72	-0.35	-0.50	0.47	0.78	0.85	0.83	0.81	-0.34	0.25	0.05

Table 17. Health factor correlations to life expectancy

4. Discussion

We found that based on objective and subjective health data that the healthiest council district is the 1st district located in west Richmond while the least healthy district is the 6th district, located in east side of the city. Life expectancy in the 1st district is 82.24 years which is 13.04 years greater than the 6th district's 69.20 years. Subjective measures between the districts show the same pattern with feeling physically unhealthy 2 weeks in the last month being 57% less prevalent in the 1st compared to the 6th district, and feeling mentally unhealthy 2 weeks of the last month was 43% less prevalent in the 1st relative to the 6th district.

More broadly, the objective and subjective health data also show a pattern of the western and particularly the northwestern portion of the city being healthier and the east and southeast being less healthy. The top three districts for life expectancy (1st, 2nd, and 4th districts) are all in the northwest quadrant of the city, whereas the lowest three districts for life expectancy are all in the city's east and southeast with the central districts being in the middle of most metrics. Using lack of insurance, prior to state Medicaid expansion, as a proxy for socioeconomic status the same pattern emerges. Socioeconomic status is a likely driving factor for the health disparity across the city.

Comparing utilization of preventive services among the districts a less stark pattern emerges with some of the healthiest districts utilizing preventive services at lower rates compared to the less healthy districts. However, when looking at services recommended for older adults, including colorectal cancer screening and core preventive services recommended for adults >65 years old the same pattern emerges with the city's west districts getting services at a much higher rate than the city's east and southeast districts. The less healthy districts were in general more likely to have had a PCP visit in the last year, but this may be related to having more health needs. Overall, preventive care for women including mammograms and PAP tests was high in all districts.

The health outcomes follow the same pattern regarding council district distribution, and this is expected as there are well established connection between the unhealthy behaviors and negative health outcomes. The disparity of rates of asthma among districts is interesting as it has a less clear association with health behaviors, yet it is following the same general distribution pattern. This may be related to air quality differences in between the districts, as exposure to air pollution has been linked to increased prevalence of asthma [12].

Differences among districts in health behaviors are especially pronounced. Comparing the lowest and highest districts, smoking, physical inactivity, obesity, and poor sleep (<7 hrs) are 2.16, 2.62, 1.89, and 1.49 times as prevalent. Again a stark pattern emerges with districts 1, 2, and 4 engaging in each of these behaviors the least while districts 6, 8, and 9 are the most. Looking at the correlation data, these four health behaviors all have a strong negative correlation (>[-0.80]) with life expectancy and a positive correlation with nearly all of the negative health outcomes. To understand why health behaviors differ widely between districts it is important to consider how the differences in environment, resources, education, and socioeconomic status are contributing to the findings.

Regarding obesity, a quick survey of Richmond shows that there are many less grocery stores in districts with the highest obesity levels. Lack of grocery stores and lower economic means are likely tremendous barriers to healthy eating for this population. Education about nutrition and weight loss strategies may also be lacking, so targeting education programs in these council districts could be a very empowering means to change.

Further analysis into physical activity disparities may be related to infrastructure and perceived safety. In general, walkability and bikeability are poorer south of the River. Safety factors into activity two-fold; if people feel unsafe being active because of lack of pedestrian infrastructure (i.e. sidewalks, crosswalks, bike lanes) they are less likely to bike or walk near their home and if they fear becoming a victim of a crime they are also unlikely to venture out of their home.

Differences in smoking rates among the city council districts is definitely multifactorial and may be difficult to unpack. There is a well-established pattern that people from low socioeconomic backgrounds smoke at higher rates [13]. This is also a problem of our youth having access to cigarettes, as we understand that about 95% of adult smokers began before age 21 [14]. Richmond has a child poverty rate of 39% according to the Annie E. Casey Foundation putting them at a higher risk of smoking [15]. Richmond, Virginia has the second lowest cigarette tax in the nation at $0.30 per pack and we know that adolescents are less likely to smoke the higher the cigarette tax is—again putting our local children at increased risk [14]. Establishing a cigarette tax would be a tremendous strategy to reduce the disparity of smoking rates in the city. Revenue generated from the tax could be used for anti-tobacco programs and potentially for the nutrition education program mentioned above.

The disparity seen in getting adequate nightly sleep is also likely multifactorial and complex. In general, being in poor health may alone be the driver of getting poor sleep. Obesity-related obstructive sleep apnea, uncontrolled diabetes- related night time urinary frequency, and potentially higher levels of stress could all derail sleep. It would be interesting to see if addressing some of the other health issues facing these communities would also help with sleep.

Community engagement, ideally led by our city council representatives, will be a very important in better understanding the factors contributing to poor eating habits, physical inactivity, smoking, and inadequate sleep. Communication with the communities facing these health disparities will allow for targeted and collaborative efforts to address their causes. Once these public health strategies are reached, our political representatives can lead the effort for their implementation.

Study limitations: The census tracts and city council district boundaries did not align perfectly. Most tracts fit perfectly within districts, but at district borders there was some crossover; in these situations the census tract was assigned to the district which had the majority of the tract. Implications to the data were likely minimal, but I would advocate for the city council districts to be drawn with consideration to keep census tract entirely within the district. Richmond districts will next be redrawn for 2023-2033, US census tracts do not change over time.

Dissemination plans: I plan to send this study to the Richmond Health District and to each of the city council representatives. I'll also consider releasing some of the figures to a Richmond-focused public forum. In the near term I intend to use these data to strengthen our ongoing efforts to establish a municipal cigarette tax in Richmond. I would also be happy to share my Excel workbook with anyone interested in further analyzing and interpreting the data.

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