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Increasing utility of Google Trends in monitoring cardiovascular disease

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Abstract

Introduction: Cardiovascular disease is the most common cause of morbidity and mortality in the United States. Patients are increasingly using internet search to find health-related information, including searches for cardiovascular diseases and risk factors. We sought to evaluate the change in the state by state correlation of cardiovascular disease and risk factors with Google Trends search volumes.

Methods: Data on cardiovascular disease hospitalizations and risk factor prevalence were obtained from the publically available Centers for Disease Control and Prevention website from 2006 to 2018. Google Trends data were obtained for matching conditions and time periods. Simple linear regression was performed to evaluate for an increase in correlation over time.

Results: Hospitalizations for six separate cardiovascular disease conditions showed moderate to strong correlation with online search data in the last period studied (heart failure (0.58, $p < .001$), atrial fibrillation (0.57, $p < .001$), coronary heart disease (0.58, $p < .001$), myocardial infarction (0.70, $p < .001$), stroke (0.62, $p < .001$), cardiac dysrhythmia (0.46, $p < .001$)) in the United States. All diseases studied showed a positive increase in correlation throughout the time period studied ($p < .05$). All five of the cardiovascular risk factors studied showed strong correlation with online search data; diabetes ($R = 0.78$, $p < .001$), cigarette use ($R = 0.79$, $p < .001$), hypertension ($R = 0.81$, $p < .001$), high cholesterol ($R = 0.59$, $p < .001$), and obesity ($p = 0.80$, $p < .001$) in the United States. Three of the five risk factors showed an increasing correlation over time.

Conclusion: The prevalence of and hospitalizations for cardiovascular conditions in the United States strongly correlate with online search volumes in the United States when analyzed by state. This relationship has progressively strengthened or been strong and stable over recent years for these conditions. Google Trends represents an increasingly valuable tool for evaluating the burden of cardiovascular disease and risk factors in the United States.

Keywords

Cardiovascular disease, Google Trends

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Introduction

Cardiovascular disease is the leading cause of morbidity and mortality in the United States as a whole as well as in the majority of states. This includes the majority of gender and racial subgroups and geographically the majority of the individual states. It is estimated that one-half of adults in the country experience some form of

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cardiovascular disease, and it spares no gender or racial subgroup.[1] The burden of these diseases disproportionately affects the elderly with greater than 70% of individuals over 60 years old experiencing some form of cardiovascular disease. It also disproportionately affects black Americans and those of lower socioeconomic status.[1–3]

Internet search has rapidly become the first place people turn to when searching for healthcare information due to its convenience and availability.[4] A total of 80% of Americans report searching the internet for health information, with 80% of those people starting at a search engine for their queries.[5] More than half of people presenting to the emergency room (ER) performed a Google search directly related to the ER complaint in the week prior to their visit.[6] In fact, an estimated 7% of total Google searches are healthcare-related, ~70,000 searches per minute, and >1 billion per day.[7] Access to healthcare information via the internet has been shown to increase patient engagement and understanding about their health.[8] However, disparities in internet access exist that in many respects are similar to the disparities seen in cardiovascular disease including the elderly, racial minorities, and those of low socioeconomic status.[9] Fortunately, these disparities have narrowed over the past 15 years. Since 2006, the percentage of adults 65 years and above using the internet has more than doubled to 73%. Similarly, black Americans have increased from 59% to 85% and low-income families have increased from 52% to 82% in the same time frame.[10]

Google Trends is a publically available information source that provides information about the relative search volume (RSV) of queried terms. The available data has been used to study a wide variety of health conditions including infectious and psychiatric diseases, and more recently chronic health conditions such as cancer and cardiovascular disease.[11–13] However, concerns remain about its validity as a useful epidemiological tool.[14]

Cardiovascular disease, with its high prevalence, would seem uniquely suited to be followed by search engine volume. Accounting for a relatively recent rise in online health search and the recent gains in online access to many of the population subgroups that are disproportionately affected by cardiovascular disease the accuracy of Google Trends for monitoring cardiovascular disease has probably increased. We hypothesized that Google Trends has become increasingly accurate for monitoring the relative prevalence of cardiovascular disease and its risk factors on a state by state basis.

Methods

Cardiovascular disease prevalence

The Centers for Disease Control and Prevention (CDC) provides public online access to hospitalizations and mortality through the Interactive Heart Disease and Stroke Atlas.[15] Hospitalizations for Medicare beneficiaries (age ≥ 65) are reported on a 3-year moving interval from 2005 to 2017. They are reported separately by primary International Classification of Diseases (ICD-10) diagnosis code for coronary heart disease (I20–I25), acute myocardial infarction (I21–I22), cardiac dysrhythmia (I47–I49), atrial fibrillation (I48.0–I48.2), heart failure (I09.81, I11.0, I13.0, I13.2, I50.1–I50.4, I50.8–I50.9), and stroke (I60–I69). Data were obtained for each of the above diagnoses in every interval available for all U.S. states and Washington D.C.; data for other U.S. territories are not consistently available and thus were not included.

Cardiovascular disease risk factor prevalence

The Behavioral Risk Factor Surveillance System (BRFSS) is the nation's premier system of health-related telephone surveys that collect state data about U.S. residents regarding their health-related risk behaviors, chronic health conditions, and use of preventive services.[16] They estimate the state-level prevalence of a variety of cardiovascular risk factors including obesity, hypertension, diabetes, hypertension, elevated cholesterol, and cigarette use. The data are provided as a cross-sectional survey for each year. However, questions vary on an annual basis and not all chronic health conditions are included each year. For example, survey results for hypertension are available for 2007, 2009, 2011, 2013, 2015, and 2017, while results are available for 2006–2017 for diabetes. Survey results are publicly available via the CDC website.

Google trends

Google Trends is an unbiased sample of Google search data that is publicly available for query.[17] Specific topics (i.e. myocardial infarction) can be searched and an relative search volume (RSV) is provided. All searches are indexed to 100, reflecting the maximum search interest (geographically or chronologically) for the time and location specified. It also provides an RSV for smaller geographic areas enclosed in a search area, for example, individual states in a search with a location of the United States. Data can be analyzed for specific words entered by the searcher or for search topics; search topics include synonyms and related searches in multiple languages. For this study, search topics were used whenever possible. Search topics do not perfectly reflect terminology used in the CDC data; thus appropriate substitutions were required, for example, coronary artery disease as opposed to coronary heart disease. The only exception to this methodology was obesity, which has previously been shown to be more closely reflected by searches for weight loss.[18] Table 1 contains the details of the search queries used for this analysis.

Table 1. Google Trends search queries and corresponding national data set terminology, time peroids and geography.

Trends search topic	CDC Term	Time period(s)	Geography
Heart failure	Heart failure	2006–2008, 2007–2009, 2008–2010, 2009–2011, 2010–2012, 2011–2013, 2012–2014, 2013–2015, 2014–2016, 2015–2017	United States
Heart arrhythmia	Cardiac dysrhythmia	2006–2008, 2007–2009, 2008–2010, 2009–2011, 2010–2012, 2011–2013, 2012–2014, 2013–2015, 2014–2016, 2015–2017	United States
Atrial fibrillation	Atrial fibrillation	2006–2008, 2007–2009, 2008–2010, 2009–2011, 2010–2012, 2011–2013, 2012–2014, 2013–2015, 2014–2016, 2015–2017	United States
Coronary artery disease	Coronary heart disease	2006–2008, 2007–2009, 2008–2010, 2009–2011, 2010–2012, 2011–2013, 2012–2014, 2013–2015, 2014–2016, 2015–2017	United States
Myocardial infarction	Acute myocardial infarction	2006–2008, 2007–2009, 2008–2010, 2009–2011, 2010–2012, 2011–2013, 2012–2014, 2013–2015, 2014–2016, 2015–2017	United States
Stroke	Stroke	2006–2008, 2007–2009, 2008–2010, 2009–2011, 2010–2012, 2011–2013, 2012–2014, 2013–2015, 2014–2016, 2015–2017	United States
Trends search topic	**BRFSS Term**	**Time period(s)**	**Geography**
Hypertension	Hypertension	2007, 2009, 2011, 2013, 2015, 2017	United States
Diabetes	Diabetes	2006, 2007, 2008, 2009, 2010, 2011, 2012, 2013, 2014, 2015, 2016	United States
Cigarettes	Cigarette use	2006, 2007, 2008, 2009, 2010, 2011, 2012, 2013, 2014, 2015, 2016, 2017, 2018	United States
Hypercholesterolemia	High cholesterol	2007, 2009, 2011, 2013, 2015, 2017	United States
Weight loss	Obesity	2006, 2007, 2008, 2009, 2010, 2011, 2012, 2013, 2014, 2015, 2016, 2017, 2018	United States

Analysis

For each of the CDC cardiovascular diseases and the BRFSS risk factors, state-level data at all time periods available were obtained from 2006 to 2018. The CDC cardiovascular disease data is released in intervals spanning 3 years; corresponding Google Trends queries were obtained, as displayed in Table 1. The BRFSS risk factors are available only sporadically through the period studied as not all risk factors are queried in each year; corresponding Google Trends queries were obtained for each available year for each risk factor also displayed in Table 1.

All analysis was performed using JMP 14.1.0. Pearson correlation coefficients were used to evaluate the correlation of prevalence of the disease or risk factor reported in each state with the RSV by state for the same time period. This has previously been used in similar analyses using Google trends.[12] An example of the analysis is displayed in Figure 1, which shows representative choropleth maps for BRFSS hypertension prevalence and Google Trends hypertension RSVs for 2017 and a corresponding plot showing their correlation. A similar analysis was performed for the condition at each time period studied.

Once correlations between each risk factor and condition with the Google Trends RSV for each year had been calculated, a simple linear regression was then performed for each condition evaluating the change correlation coefficients over the time period studied in order to identify changes in the strength of the correlation relationship over the years studied. An alpha level of .05 was used to evaluate for significance. In order to assess states that showed the least correlation with Google Trends data, the last observation period for each cardiovascular disease and risk factor was analyzed using a linear regression. Studentized residuals were calculated for each state in each model. The ten samples for each state were then averaged to obtain an average residual

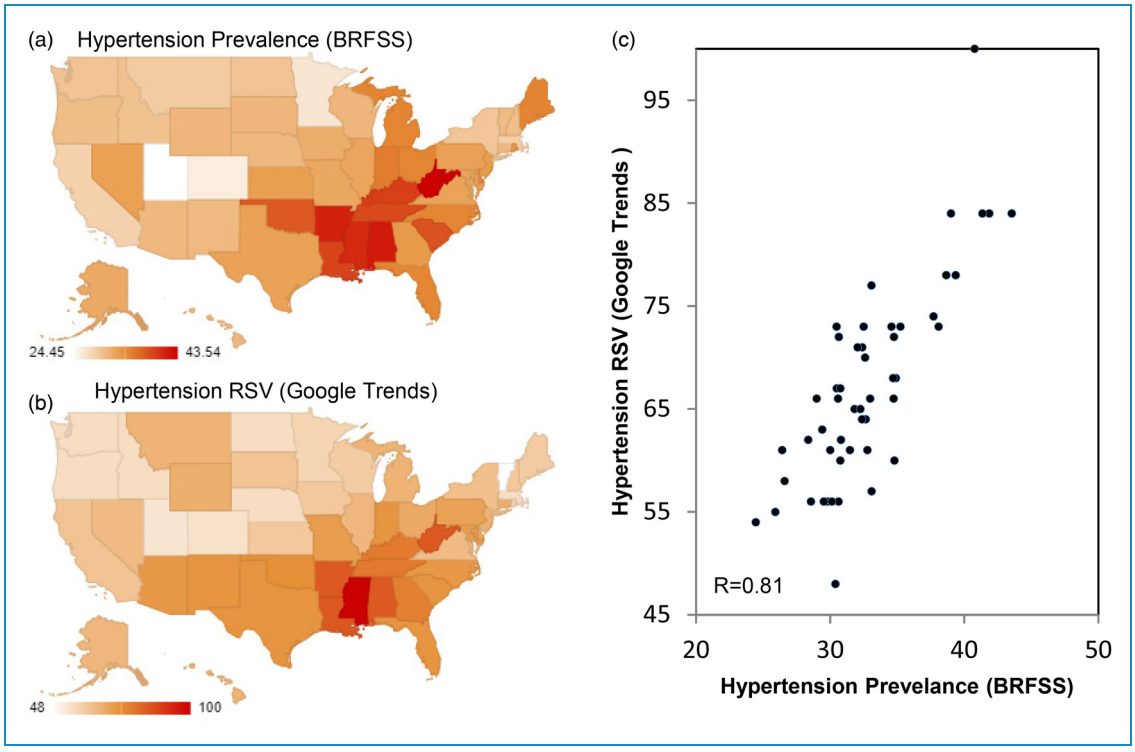

Figure 1. Choropleth maps for the prevalence or hypertension and of the RSV of hypertension in each state; scatter chart of the relationship between RSV for hypertension and BRFSS estimated prevalence of hypertension in 2017.

for each state. No Institutional Review Board (IRB) approval was obtained for this study given that all data used in this analysis are publicly available and anonymous.

Results

Six separate categories of cardiovascular disease were available for evaluation, each with 11 separate three-year time intervals. At the earliest interval studied (2005–2007), coronary artery disease ($R = 0.30$, $p < .05$), acute myocardial infarction ($R = 0.49$, $p < .05$), heart failure ($R = 0.34$, $p < .05$) and stroke ($R = 0.38$, $p < .05$) all had a modest but significant correlation with the corresponding Google Trends RSV values. Cardiac dysrhythmia and atrial fibrillation showed a non-significant positive correlation ($R = 0.21$, 0.05). In the final interval studied (2015–2017) all six categories of disease had a strong positive correlation with the corresponding Google Trends state-by-state RSV: heart failure (0.58, $p < .001$), atrial fibrillation (0.57, $p < .001$), coronary heart disease (0.58, $p < .001$), myocardial infarction (0.70, $p < .001$), stroke (0.62, $p < .001$) and cardiac dysrhythmia (0.46, $p < 0.001$). Complete results are available in Figure 2.

Five separate cardiovascular disease risk factors were available for evaluation in 1-year intervals with a minimum of six and a maximum of 13 intervals. Four of the risk factors had at least modest positive significant correlation with the corresponding Google Trends RSV on a state-by-state comparison at the earliest studied interval. Diabetes ($R = 0.52$, $p < .001$), hypertension ($R = 0.63$, $p < .001$) and obesity ($R = 0.74$, $p < .001$) all had strong correlation, while cigarette use showed a modest correlation ($R = 0.34$, $p = 0.01$). High cholesterol showed no correlation. By the final interval studied, all five cardiovascular risk factors evaluated showed a strong association with the corresponding Google Trends RSV: diabetes ($R = 0.78$, $p < .001$), cigarette use ($R = 0.79$, $p < .001$), hypertension ($R = 0.81$, $p < .001$), high cholesterol ($R = 0.59$, $p < .001$) and obesity ($R = 0.80$, $p < .001$). Complete results are available in Figure 3.

Five of the six cardiovascular diseases showed increasing strength of the correlation over time, with only cardiac dysrhythmia showing a non-significant relationship. Atrial fibrillation showed the strongest relationship ($R^2 = 0.94$, $p < .001$), but every model evaluated had an $R^2 > 0.47$ except for cardiac dysrhythmia. Complete summaries of the linear models are available in Table 2.

Three risk factors had a significant increase in the strength of correlation between the BRFSS reported prevalence and the Google Trends RSV over the time period studied: diabetes ($R^2 = 0.60$, $p = .005$), cigarette use ($R^2 = 0.69$, $p < .001$), and high cholesterol ($R^2 = 0.83$, $p = .01$). Hypertension and obesity showed a positive, but not significant, trend of increasing correlation strength with time.

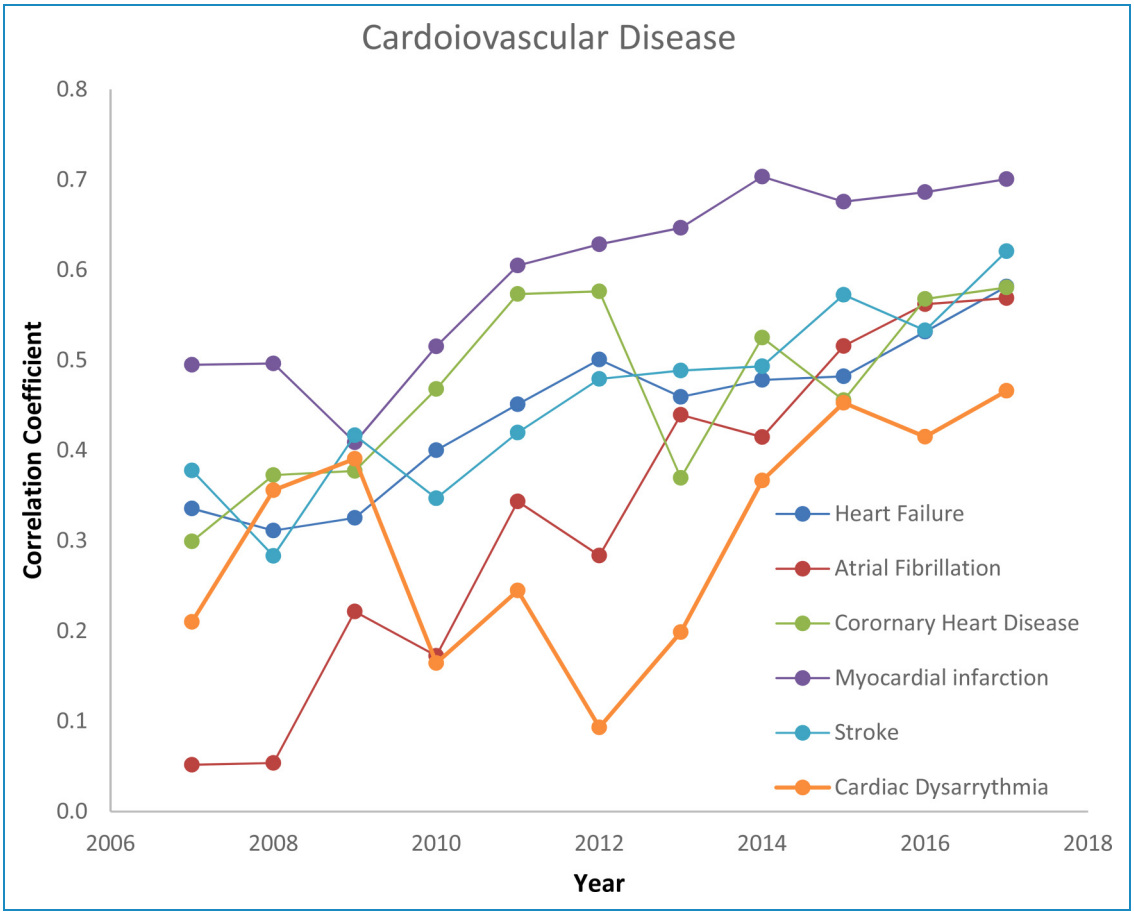

Figure 2. Online search correlations with cardiovascular diseases over time.

Complete summaries of the linear models are available in Table 2.

The average studentized residual for each state in displayed in Figure 4. In general, states located in the Southern and upper Midwestern United States have positive (red) average residuals meaning their burden of disease is higher than would be predicted using Google Trends alone. Alternatively, states located in the mountain west and northeastern United States consistently showed negative (green) average residuals representing a lower burden of disease than would be predicted by Google Trends alone.

Discussion

In this study, we show that hospitalizations for cardiovascular disease and prevalence of cardiovascular disease risk factors in the United States strongly correlate with Google Trends RSVs on a state-by-state basis. This relationship has progressively strengthened or been strong and stable over recent years for these conditions. Google Trends represents an increasingly valuable tool for evaluating the burden of cardiovascular disease and risk factors in the United States that can be expected to improve as more users use internet search to gather health-related information.

The consistent moderate to strong correlation between search data and cardiovascular disease hospitalizations is in line with the growing use of the internet and, specifically, search engines for patients and their families to find information about health conditions.[9] The strength of these relationships has uniformly increased throughout the period studied, a period in which an increasing number of patients at elevated risk for cardiovascular disease have gained access to the internet.[9] The hospitalization data only includes Medicare beneficiaries limiting it to patients 65 years and above. Since an estimated 27% of this age group does not actively use the internet, it's foreseeable that this relationship will continue to strengthen over the next several years as people using the internet enter this age group or those 65 years and above become active on the internet.[10] Of the six disease states evaluated, cardiac dysrhythmia, while still significant, had the poorest association. This may be because cardiac dysrhythmia is an umbrella term comprised of several diagnoses with completely separate terminology (e.g. supraventricular tachycardia or atrial flutter), as opposed to the other conditions,

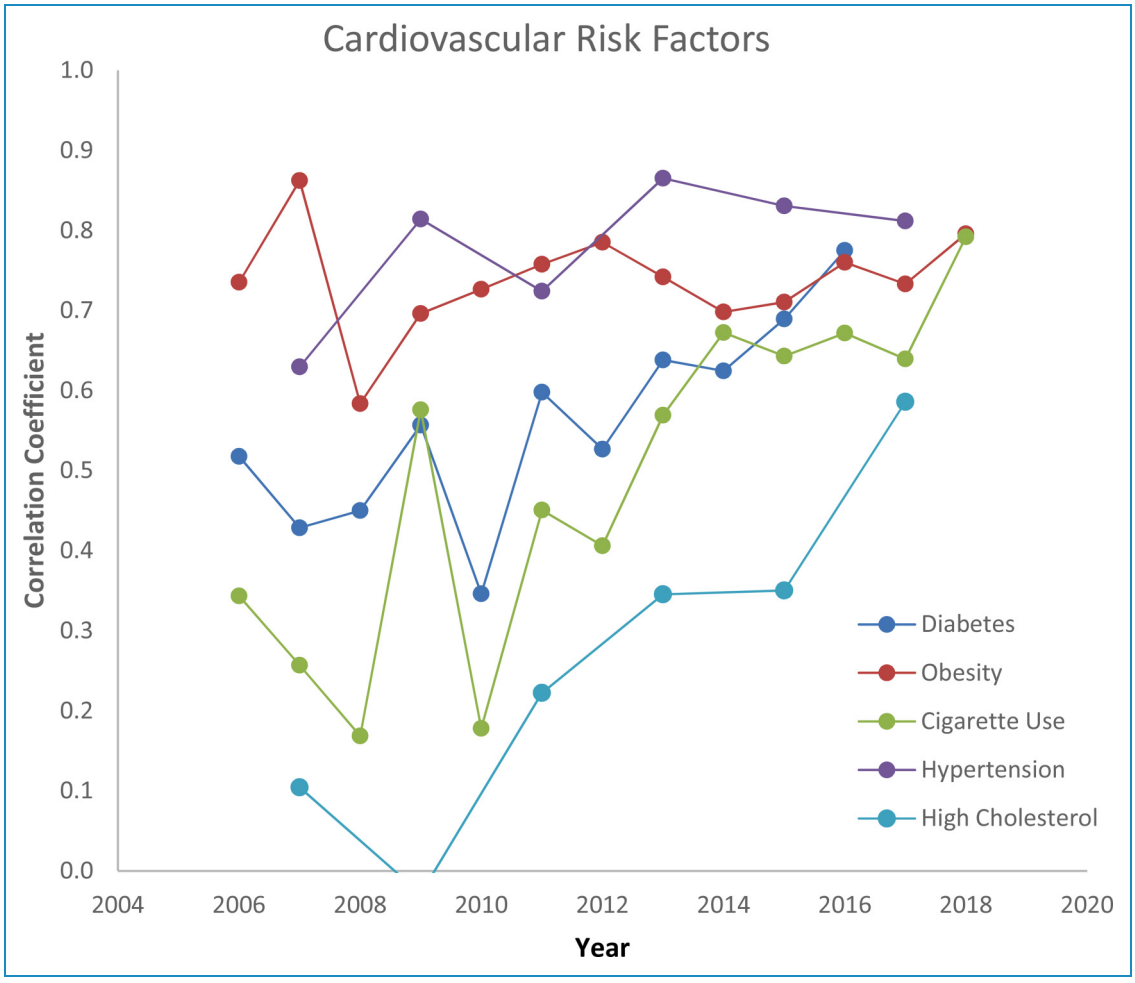

Figure 3. Online search correlations with cardiovascular risk factors over time.

which have more overlap in terminology (heart failure with preserved ejection fraction and heart failure with reduced ejection fraction).

All of the cardiovascular risk factors assessed had a strong correlation with the survey data from BRFSS. Hypertension and diabetes did not show a significant increase in correlation over time. However, this is predominately because they exhibited a strong correlation from the earliest interval studied and thus had little room to improve. The strength of the correlation was consistently higher in cardiovascular risk factor comparisons as opposed to hospitalizations. There are several possible etiologies for this. Firstly, survey data includes American adults over 18 years of age as opposed to solely Medicare beneficiaries in the hospitalization data. Secondly, hospitalization data is coded based on the primary diagnosis for the hospitalization without accounting for commonly concurrent conditions such as atrial fibrillation and heart failure while BRFSS data asks about cardiovascular risk factors independently. Thirdly, by virtue of being a survey, BRFSS depends on participants having knowledge of their conditions to report them; this is also required to search for health information on the topic. Hospitalization data can be reported without the patient ever fully grasping their specific diagnosis.

In addition to closely correlating with both hospitalizations and risk factor prevalence, online search data has the distinct advantage of being free of cost and nearly real time.[19] Both CDC hospitalizations data and the BRFSS provided increased granularity and demographic subgrouping that are extremely valuable in the study of cardiovascular disease. However, data from these sources typically requires years before it becomes available for study. If online search data continues to improve in its accuracy, as would be expected based on current trends, it may eventually provide an accurate enough tool to allow for early investigation of changes in cardiovascular disease prevalence. This would allow for more rapid mobilization of resources to help combat the leading cause of morbidity and mortality in the country. Another possible benefit is the use of online search data to investigate cardiovascular conditions not currently included in national statistics, providing preliminary data on prevalence.

Table 2. Time and correlation linear model summaries.

	R^2	RMSE	F	Intercept	Coefficient	p
Heart failure	0.88	0.03	64.20	−48.94	0.02	<.0001*
Atrial fibrillation	0.94	0.05	141.42	−111.61	0.06	<.0001*
Coronary heart disease	0.48	0.08	8.40	−42.70	0.02	.0177*
Myocardial infarction	0.81	0.05	39.63	−54.82	0.03	.0001*
Stroke	0.83	0.04	43.32	−54.42	0.03	.0001*
Cardiac dysrhythmia	0.24	0.12	2.81	−37.40	0.02	.1278
Diabetes	0.60	0.08	13.77	−56.84	0.03	.0048*
Obesity	0.02	0.07	0.17	−3.46	0.00	.6852
Cigarette use	0.69	0.12	24.21	−86.62	0.04	.0005*
Hypertension	0.46	0.07	3.39	−30.87	0.02	.1393
High cholesterol	0.83	0.10	20.02	−105.11	0.05	.011*

*indicates p <0.05.

This study highlights areas of the country in which Google Trends may over- or underestimate the burden of cardiovascular disease. The reasons for these discrepancies are unclear; however, there are several possibilities. These include internet access, socioeconomic disparities, differing demographics with regards to age and race, and educational disparities. Another possibility would be access to care, with people having more difficulty accessing care

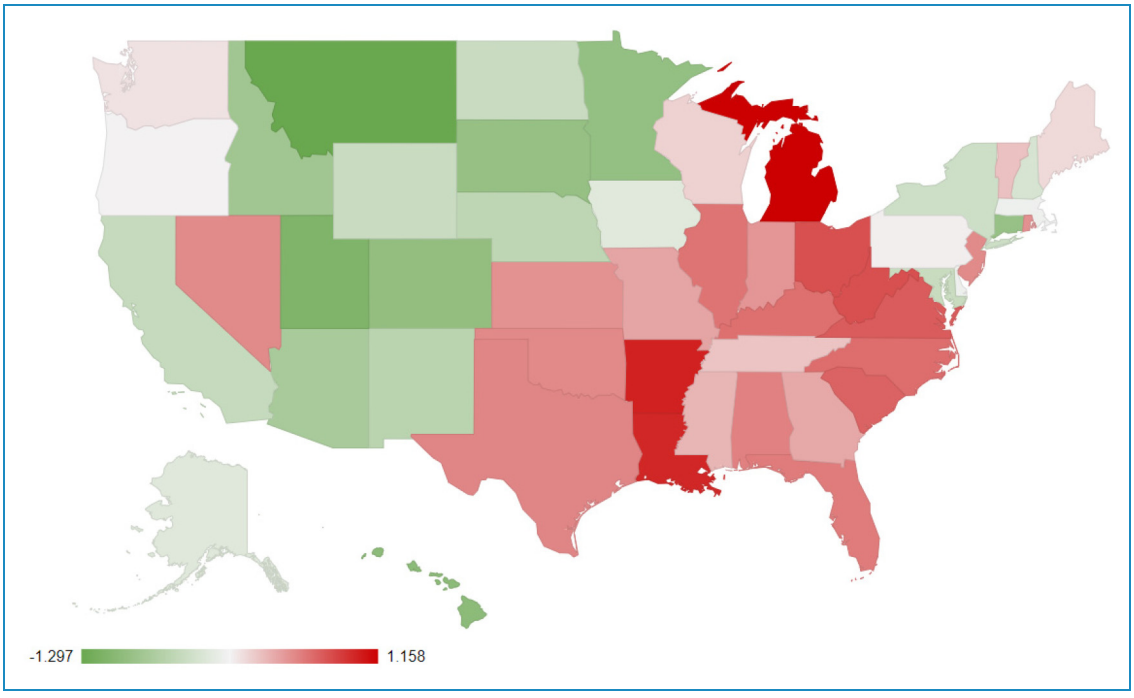

Figure 4. Average studentized residuals displayed a choropleth of the United States. Red represents high residuals (underestimation of disease), green represents low residuals (overestimation of disease).

potentially utilizing internet search more frequently. Further work evaluating these possibilities is required.

Patient awareness of cardiovascular conditions is associated with improved outcomes.[20] It is interesting to consider search data as a possible surrogate for patient awareness, as awareness is required to perform an online search. By comparing this surrogate for awareness with measures of cardiovascular disease and risk factor control it may be possible to identify areas of high disease burden but relatively low search volume that should be targeted for more intensive cardiovascular health education interventions on a statewide scale. Similarly, areas with high relative search volume as compared to disease burden may be identified as models and studied to help look for transferable practices that can lead to increased patient awareness. This study also highlights the important need for accurate disease-specific materials available online, given the volume of people using this as an information source and the diagnostic specificity with which they are searching. Recent work has shown that among prominent cardiovascular societies, patient-specific online materials are consistently written above recommended grade levels.[21] Every effort should be made to make these resources applicable to a broad audience.

There are clear limitations to this study given the nature of online search data. Online search data is anonymous and thus demographic data is not available. Similarly, specific health information about the searcher is not available to confirm the presence of a condition and motivation for online search. This study relies on the correlation between national data sets that have an inherent margin of error, which could skew the results of correlation with online trends in either direction.

Overall, our study highlights the strong correlation of search engine data with cardiovascular conditions at a state level as well as the increasing strength of these relationships throughout the period studied. Based on this improvement, online search data can be expected to become an increasingly valuable tool in cardiovascular research in providing nearly real-time information without public cost.

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Conflict of interest: The authors certify that they have no affiliations with or involvement in any organization or entity with any financial interest or non-financial interest in the subject matter or materials discussed in this manuscript.

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