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ORIGINAL ARTICLE | DIGITAL DIVIDE

Digital Divide: Marked Disparities in Computer and Broadband Internet Use and Associated Health Inequalities in the United States

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ABSTRACT

Background: Despite the considerable increase in computer and internet use over the past two decades, few studies have examined socioeconomic, demographic, and health characteristics associated with computer and internet use in the United States. Community-level differences in computer and internet use and associated disparities in health and mortality indicators have not been analyzed. This study examines these associations at the individual and community level using national census, health, and mortality data.

Methods: We analyzed data from the 2017 American Community Survey (ACS) Micro-data Sample, the 2013-2017 ACS Summary File, National Vital Statistics System, and 2019 County Health Rankings and Roadmaps. Health and socioeconomic characteristics associated with broadband internet and computer use among adults aged ≥18 were modeled by logistic regression (N=2,385,595).

Results: In 2017, 89.7% of Asian/Pacific Islanders (APIs) had broadband internet service, compared with 66.0% of American Indians/Alaska Natives (AIANs), 77.2% of Blacks/African-Americans, 78.8% of Hispanics, and 83.5% of non-Hispanic Whites. APIs (97.4%) were more likely than other racial/ethnic groups to own or use a computer (including smartphones), while AIANs (80.3%) were less likely. Socioeconomic gradients in internet and computer use were marked. Those below the poverty level and with less than a high school education reported 18 and 15 percentage points lower rates of internet and computer use respectively. Compared to metropolitan areas, nonmetropolitan areas had lower internet access (80.3% vs. 69.7%) and computer use (88.4% vs. 80.5%). Rural areas and small urban towns had the lowest level of internet and computer use. Risks of disabilities and lack of health insurance were greater among persons with lower broadband internet and computer access. Communities with low internet and computer use had seven years shorter life expectancy than communities with high use and were at increased risks of mortality from various chronic conditions, poor health, mental distress, hospitalization, smoking, obesity, and physical inactivity.

Conclusions and Implications for Translation: Significant socioeconomic and racial/ethnic disparities in internet and computer use and associated health inequalities exist in the US. Closing the social divide in internet and computer use can positively impact individual empowerment, educational attainment,

economic growth, community development, access to health care and health-related information, and health promotions efforts.

Keywords: • Digital Divide • Broadband Internet • Computer Use • Disability • Health Insurance • Cause-Specific Mortality • Morbidity • Health Behaviors

1. Introduction

Access to and use of computers and internet are widespread and have had a considerable impact on many aspects of social and economic life in the United States during the past two decades.[1] Both computer and internet use have profound effects not only on individual empowerment, educational attainment, economic growth, and community development, but also in accessing health care, health-related information, health education and health promotions efforts, and, are seen as an important social determinant of health.[1,2] Broadband (high-speed) internet access and computer use offer a unique option for vulnerable populations and disadvantaged communities that may face challenges accessing health care due to transportation, finances, or disability. In addition, the widespread use of mobile devices in racial/ethnic and low-resourced communities presents an opportunity for increased utilization of digital health.[13]

However, despite the considerable increase in computer and internet use over the past two decades, few studies have examined socioeconomic, demographic, and health characteristics associated with computer and internet use in the US.[1,4] Analysis of how community-level differences in computer and internet use are related to geographic disparities in health, disease, and socioeconomic characteristics is also lacking. To address these gaps in data and research, this study examines these associations at the individual and community level using recent data from the American Community Survey (ACS) and the other national health and disease databases.

2. Methods

2.1. Data Sources

Data for the present analysis came from the 2017 American Community Service (ACS) Micro-data Sample, the 2013-2017 ACS Summary File, the National Mortality Database, and the County Health Rankings and Roadmaps.[5-11] The ACS is the primary census database for producing socioeconomic, demographic, housing, and labor force characteristics of various population groups at the national, state, county, and local levels.[7-10,12] The unique advantage of the ACS is that it is conducted annually with a sample size of over 3 million records.[7,9,12] The ACS uses a complex, multistage probability design and is representative of the civilian non-institutionalized population, covering all communities in the US.[7-10,12] The household response rate for the ACS exceeds 98%.[7,12] All data are based on self-reports obtained via mail-back or online questionnaires, telephone, interviews or in-home personal interviews.[7,9,12] Substantive and methodological details of the ACS are available in census and previous publications.[7-10,12] The National Mortality Database, maintained by the National Center for Health Statistics, contains annual as well as temporal mortality data by age, sex, race/ethnicity, cause of death, place of death, and other demographic characteristics.[5,6] The mortality database was used to calculate age-adjusted all-cause and cause-specific mortality rates at the county level for the period 2013-2017. The County Health Rankings and Roadmaps database, compiled by the Robert Wood Johnson Foundation, provided county-level data on life expectancy, health, morbidity, and health-risk behaviors from 2014 to 2017.[11]

2.2. Dependent Variables

To analyze sociodemographic disparities in internet and computer use at the individual level, we used broadband internet access and computer access as dependent variables. In the 2017 ACS, broadband internet access was defined as whether the respondent or any member of a household had

broadband (high-speed) internet service such as cable, fiber optic, or DSL (digital subscriber line) service installed in that household.[1,7-10] Computer access was defined by whether the respondent or any member of the household owned or used any of the following types of computer: desktop, laptop, smartphone, tablet or other portable wireless computer, or some other type of computer.[1,7-10] In the 2013-2017 ACS Summary File, the area-level indicator of internet access was defined as the percentage of households with an internet subscription that included broadband service, cellular data plan, satellite, fixed wireless, or dialup service.[1,7,9,10]

To analyze health characteristics associated with internet and computer use at the individual level, we considered disability status and health insurance status as outcomes variables. Disability status and health insurance status are the only health-related variables available in the ACS. Analyses of disability status and health insurance status were carried out for 2,385,595 individuals aged ≥18 years. The ACS defined individuals as having a disability if they reported serious vision, hearing, cognitive, ambulatory, self-care, or independent living difficulties.[7-10,12] The ACS concept of disability captures these six aspects of disability to define an overall measure or specific disability types.[7-10,12] To derive *vision-related disability*, the ACS respondents are asked if they are "blind or …have serious difficulty seeing even when wearing glasses." *Hearing difficulty* is derived from a question that asks respondents if they are "deaf or …have serious difficulty hearing." *Cognitive difficulty* involves serious difficulty concentrating, remembering, or making decisions due to a physical, mental, or emotional condition. *Ambulatory difficulty* is based on a question that asks respondents if they have "serious difficulty walking or climbing stairs." *Self-care difficulty* is based on the question whether or not the respondent has difficulty dressing or bathing. *Independent living difficulty* is determined if the respondent reports having difficulty doing errands alone such as visiting a doctor's office or shopping due to a physical, mental, or emotional condition.[7-10,12]

In addition to the individual-level disability and health insurance variables, we considered a number of health, morbidity, mortality outcomes at the area (county and Zip code) level, including life expectancy, all-cause and cause-specific mortality rates, disability rates, health insurance rates, hospital admissions rates, and prevalence of mental distress, poor health, smoking, physical inactivity, and obesity.[5,6,10,11,13]

2.3. Independent Variables

Race/ethnicity was classified into 6 categories as shown in Table 1 and included the major racial/ethnic groups such as non-Hispanic Whites, non-Hispanic Blacks/African-Americans, American Indians/Alaska Natives (AIANs), Asian/Pacific Islanders (APIs), Hispanics, and a residual category of other races that included multiple race groups. Nativity/immigrant status was defined on the basis of an individual's place of birth. US-born were those born in one of the 50 states, Washington, DC, or one of the US territories. Immigrant or foreign-born refers to those born outside these areas and who were not a US citizen at birth.[7-10,12]

Using the social determinants of health framework and past research as a guide, we considered, in addition to race/ethnicity and immigrant status, the following sociodemographic covariates that are known to be associated with disability and health insurance: age, gender, marital status, educational attainment, poverty status, employment status, housing tenure, and region of residence.[12,13] These covariates were measured as shown in Table 1.

2.4. Statistical Methods

Multivariate logistic regression was used to model the association between race/ethnicity and socioeconomic factors and the binary outcomes of broadband internet access, computer use, disability, and health insurance.[14] The two-sample *t* test was used to test the difference in prevalence between any two groups. To examine area-level associations, Zip-code and county-level correlations between computer and internet use and health, mortality, and socioeconomic characteristics were computed and tested for statistical significance. Analyses were carried out using SAS Version 9.4.[14]

Table 1: Prevalence and unadjusted and adjusted odds of broadand Internet access and computer use among US adults aged ≥ 18 years according to racial/ethnic, socioeconomic, and demographic characteristics: The 2017 American Community Survey

Sociodemographic groups	Broadband Internet (N=2,090,921)							Computer use (N=2,385,595)						
	Prevalence	Unadjusted odds ratio			Adjusted odds ratio[1]			Prevalence	Unadjusted odds ratio			Adjusted odds ratio[1]		
	%	OR	95% CI		OR	95% CI		%	OR	95% CI		OR	95% CI	
Age group (years)														
18-24	82.74	1.16	1.15	1.18	1.65	1.63	1.69	97.75	9.03	8.77	9.30	19.84	19.18	20.53
25-34	84.13	1.29	1.27	1.30	1.43	1.41	1.46	97.71	8.88	8.68	9.08	10.53	10.24	10.83
35-44	84.68	1.34	1.33	1.36	1.42	1.40	1.44	97.53	8.21	8.03	8.40	7.44	7.25	7.64
45-54	83.45	1.23	1.21	1.24	1.25	1.23	1.27	96.21	5.28	5.19	5.37	4.26	4.17	4.35
55-64	81.52	1.07	1.06	1.08	1.08	1.06	1.09	93.32	2.91	2.87	2.95	2.37	2.33	2.41
≥65	80.46	1.00	Reference		1.00	Reference		82.78	1.00	Reference		1.00	Reference	
Gender														
Male	82.91	1.03	1.02	1.04	1.01	1.00	1.01	93.40	1.13	1.12	1.15	0.83	0.82	0.84
Female	82.47	1.00	Reference		1.00	Reference		92.59	1.00	Reference		1.00	Reference	
Race/ethnicity														
Non-Hispanic White	83.52	1.00	Reference		1.00	Reference		93.30	1.00	Reference		1.00	Reference	
Non-Hispanic Black	77.18	0.67	0.66	0.68	0.83	0.82	0.84	88.24	0.54	0.53	0.55	0.82	0.81	0.84
Hispanic	78.79	0.73	0.73	0.74	0.87	0.86	0.88	93.19	0.98	0.97	1.00	0.95	0.94	0.97
American Indian/AN	65.98	0.38	0.37	0.40	0.48	0.46	0.5	80.25	0.29	0.28	0.30	0.33	0.32	0.34
Asian/Pacific Islander	89.68	1.72	1.68	1.75	1.38	1.35	1.41	97.38	2.67	2.59	2.77	1.51	1.45	1.57
All other groups[2]	84.24	1.06	1.03	1.09	1.05	1.02	1.08	94.91	1.34	1.28	1.4	0.99	0.94	1.04
Immigrant status														
Immigrant	83.35	1.06	1.05	1.07	1.09	1.07	1.10	94.42	1.33	1.31	1.35	1.39	1.36	1.42
US-born	82.57	1.00	Reference		1.00	Reference		92.73	1.00	Reference		1.00	Reference	
Marital status														
Married	84.25	1.00	Reference		1.00	Reference		95.72	1.00	Reference		1.00	Reference	
Widowed	78.42	0.86	0.86	0.87	0.93	0.92	0.94	73.57	0.69	0.68	0.69	0.38	0.38	0.39
Divorced/separated	77.77	0.65	0.65	0.66	0.86	0.85	0.87	89.08	0.37	0.36	0.37	0.59	0.58	0.60
Never married	82.18	0.68	0.67	0.69	1.01	0.99	1.02	93.87	0.13	0.12	0.13	0.43	0.42	0.44
Education (years of schooling completed)														
0-11	72.26	0.30	0.30	0.30	0.41	0.41	0.42	80.47	0.08	0.08	0.08	0.18	0.17	0.18
12	76.99	0.39	0.38	0.39	0.49	0.49	0.50	88.89	0.15	0.15	0.16	0.29	0.28	0.29

Contd...

Table 1: ***(Continued)***

Sociodemographic groups	Broadband Internet (N=2,090,921)							Computer use (N=2,385,595)						
	Prevalence	Unadjusted odds ratio			Adjusted odds ratio[1]			Prevalence	Unadjusted odds ratio			Adjusted odds ratio[1]		
	%	OR	95% CI		OR	95% CI		%	OR	95% CI		OR	95% CI	
13-15	82.49	0.54	0.54	0.55	0.66	0.65	0.66	95.73	0.43	0.42	0.44	0.62	0.61	0.63
≥16	89.66	1.00	Reference		1.00	Reference		98.12	1.00	Reference		1.00	Reference	
Poverty status (ratio of family in cometopoverty threshold)														
<100%	72.90	0.35	0.34	0.35	0.48	0.48	0.49	83.65	0.10	0.09	0.10	0.22	0.22	0.23
100-199%	75.35	0.39	0.39	0.40	0.55	0.54	0.56	85.34	0.11	0.11	0.11	0.26	0.25	0.26
200-299%	79.44	0.50	0.49	0.50	0.66	0.65	0.66	91.55	0.20	0.20	0.21	0.39	0.38	0.4
300-399%	82.41	0.60	0.60	0.61	0.74	0.73	0.75	94.87	0.35	0.34	0.35	0.55	0.53	0.56
400-499%	84.53	0.70	0.69	0.71	0.82	0.81	0.83	96.44	0.51	0.49	0.52	0.69	0.67	0.71
≥500%	88.61	1.00	Reference		1.00	Reference		98.16	1.00	Reference		1.00	Reference	
Employment status														
Unemployed	79.00	0.71	0.69	0.72	0.96	0.94	0.98	94.49	0.51	0.49	0.52	0.92	0.88	0.95
Not in laborforce	80.07	0.75	0.75	0.76	1.04	1.03	1.05	85.96	0.18	0.18	0.18	0.66	0.65	0.67
Employed	84.20	1.00	Reference		1.00	Reference		97.13	1.00	Reference		1.00	Reference	
Housing tenure														
Renter	79.27	0.74	0.73	0.74	0.87	0.86	0.88	90.39	0.61	0.6	0.61	0.65	0.64	0.66
Owner	83.84	1.00	Reference		1.00	Reference		93.93	1.00	Reference		1.00	Reference	
Geographic region														
Northeast	87.44	1.30	1.29	1.32	1.26	1.24	1.27	93.15	0.73	0.71	0.74	0.75	0.73	0.76
Midwest	79.89	0.74	0.74	0.75	0.76	0.75	0.77	92.06	0.62	0.61	0.63	0.67	0.66	0.69
South	80.95	0.80	0.79	0.80	0.84	0.83	0.85	92.18	0.63	0.62	0.64	0.74	0.72	0.75
West	84.22	1.00	Reference		1.00	Reference		94.94	1.00	Reference		1.00	Reference	

OR= odds ratio; SE= standard error; CI= confidence interval; AN=Alaska Native.

[1]Adjusted by logistic regression model forage, gender, race/ethnicity, immigrant status,marital status, education, poverty status, employment status, and geographic region. [2]This category includes multiple race groups.

Table 2: Prevalence and unadjusted and adjusted odds of disability and health insurance according to broadband Internet access and computer use Among US adults aged ≥ 18 years: The 2017 American Community Survey (N= 2,090,921)

Disability and health insurance	Prevalence	Unadjusted odds ratio			Adjusted odds ratio[1]				Prevalence	Unadjusted odds ratio			Adjusted odds ratio[1]		
	%	OR	95% CI		OR	95% CI			%	OR	95% CI		OR	95% CI	
Overall Disability								Independent Living Disability							
Broadband Internet								Broadband Internet							
Yes	13.02	1.00	Reference		1.00	Reference		Yes	4.48	1.00	Reference		1.00	Reference	
No	17.39	1.41	1.39	1.43	1.02	1.02	1.04	No	5.94	1.35	1.33	1.37	0.95	0.93	0.97
Computer use								Computer use							
Yes	14.24	1.00	Reference		1.00	Reference		Yes	4.89	1.00	Reference		1.00	Reference	
No	39.74	3.61	3.50	3.73	1.42	1.37	1.47	No	18.46	4.27	4.10	4.46	1.52	1.45	1.59
Cognitive/Mental Disability								Hearing Disability							
Broadband Internet								Broadband Internet							
Yes	3.97	1.00	Reference		1.00	Reference		Yes	4.09	1.00	Reference		1.00	Reference	
No	5.50	1.41	1.38	1.43	1.00	0.99	1.01	No	5.34	1.32	1.30	1.35	1.07	1.05	1.09
Computer use								Computer use							
Yes	4.41	1.00	Reference		1.00	Reference		Yes	4.43	1.00	Reference		1.00	Reference	
No	13.10	3.32	3.16	3.48	1.43	1.36	1.51	No	13.68	2.88	2.74	3.03	1.32	1.25	1.40
Ambulatory Disability								Vision Disability							
Broadband Internet								Broadband Internet							
Yes	6.76	1.00	Reference		1.00	Reference		Yes	2.18	1.00	Reference		1.00	Reference	
No	9.45	1.44	1.42	1.46	1.01	1.00	1.02	No	3.00	1.39	1.36	1.42	1.02	1.00	1.04
Computer use								Computer use							
Yes	7.54	1.00	Reference		1.00	Reference		Yes	2.44	1.00	Reference		1.00	Reference	
No	25.81	3.97	3.82	4.12	1.32	1.27	1.38	No	8.24	3.32	3.12	3.53	1.36	1.28	1.45
Selfcare Disability								No Health Insurance							
Broadband Internet								Broadband Internet							
Yes	2.25	1.00	Reference		1.00	Reference		Yes	6.47	1.00	Reference		1.00	Reference	
No	3.08	1.38	1.35	1.41	0.97	0.95	1.00	No	11.44	1.87	1.85	1.89	1.29	1.28	1.31
Computer use								Computer use							
Yes	2.48	4.44	4.22	4.69	1.51	1.43	1.60	Yes	7.76	1.00	Reference		1.00	Reference	
No	9.66	1.00	Reference		1.00	Reference		No	10.04	1.37	1.30	1.45	1.11	1.04	1.18

OR= odds ratio; SE= standard error; CI= confidenceinterval; AN= AlaskaNative. [1]Adjusted by logistic regression model forage, gender, race/ethnicity, immigrantstatus,marital status, education, poverty status, employment status, and geographic region.

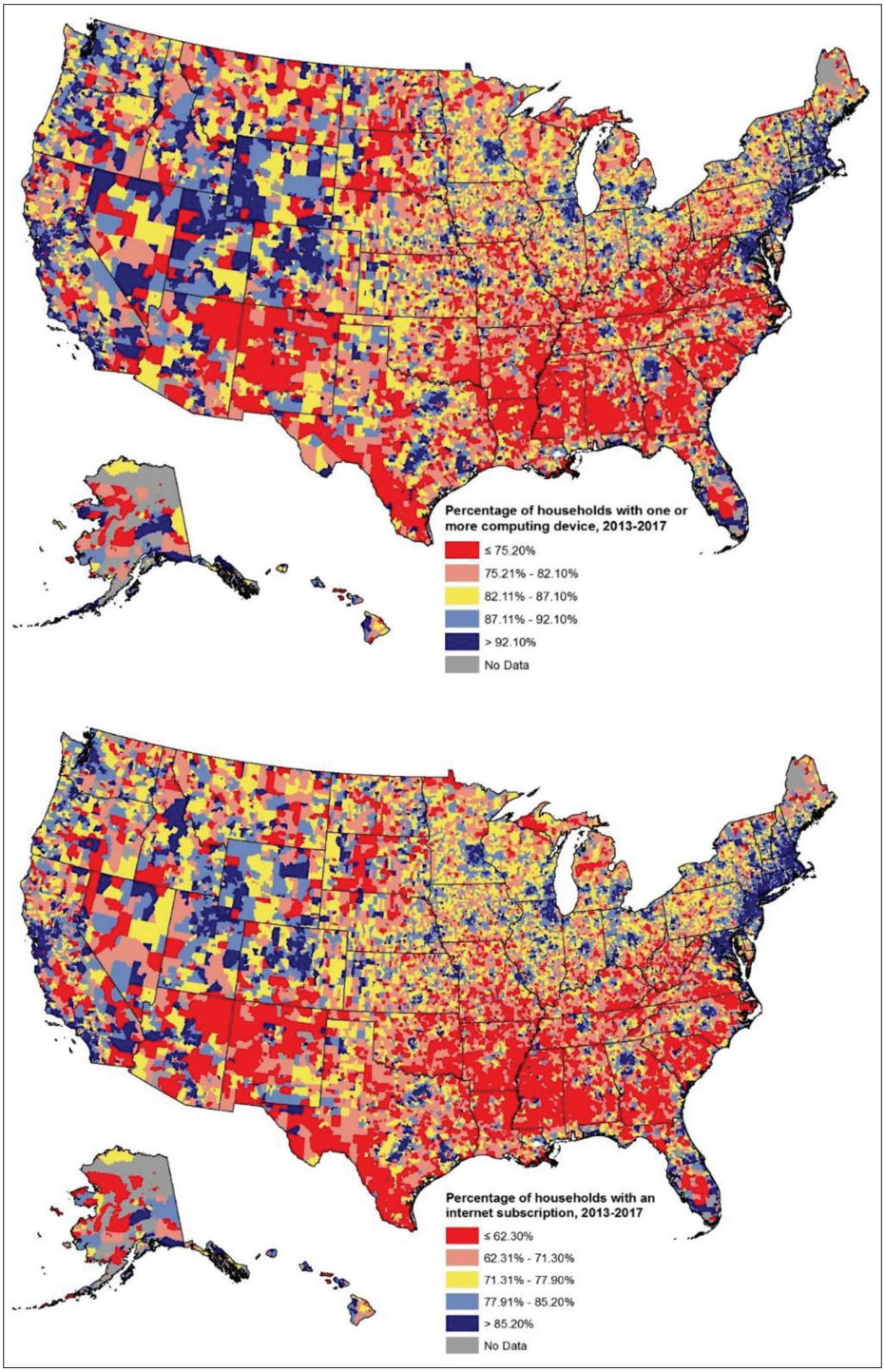

Figure 1: Percentage of Households with Computer and Internet Access, United States, 2013-2017 (32,989 Zip Codes)
Source: Data derived from the 2013-2017 American Community Survey.

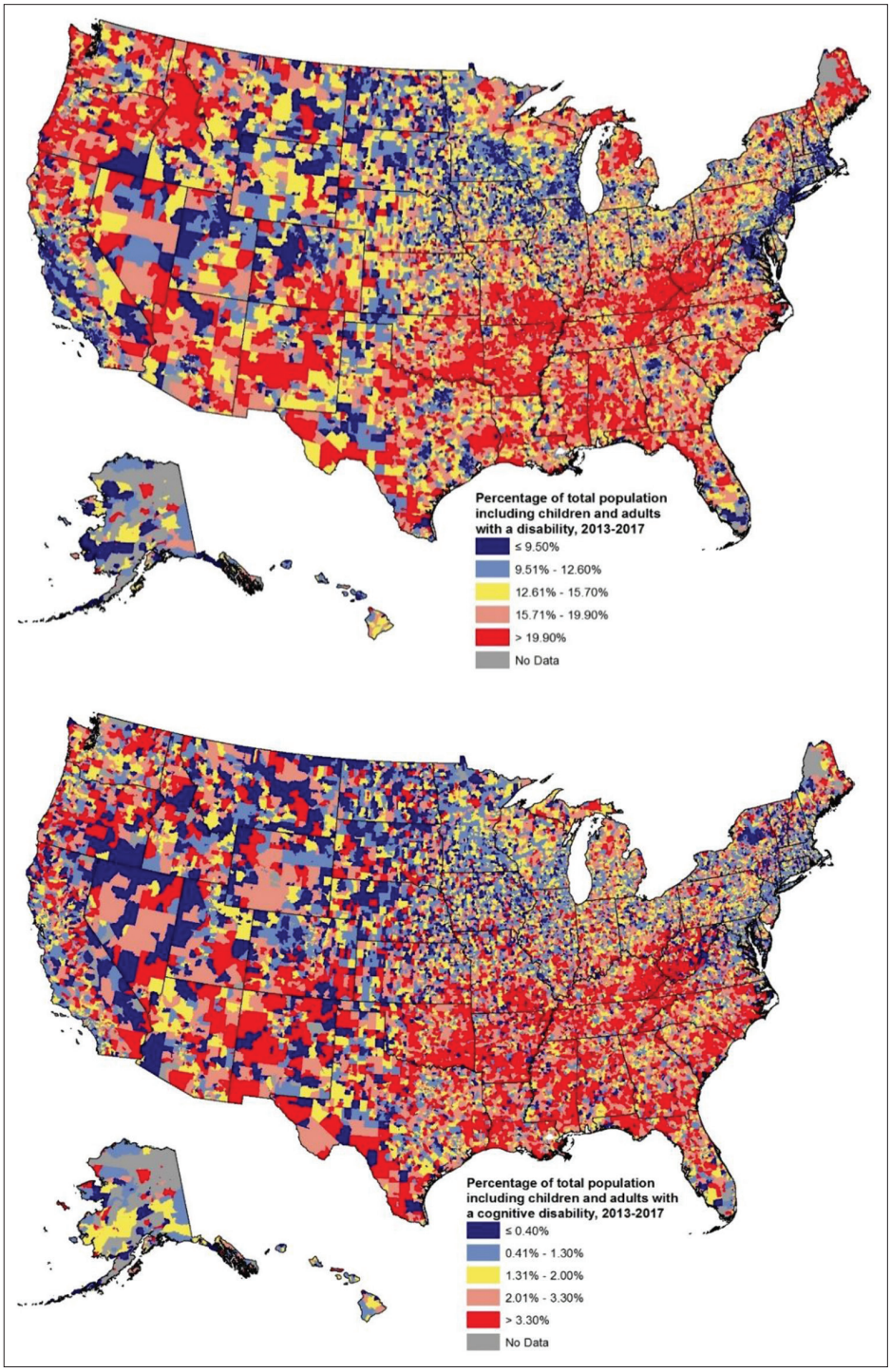

Figure 2: Overall Disability and Cognitive Disability Rates, United States, 2013-2017 (32,989 Zip Codes)
Source: Data derived from the 2013-2017 American Community Survey.

Table 3: Correlations between internet and computer use and selected health, mortality, and sociodemographic characteristics, United States, 2013-2017 (N = 32,989 Zip codes and 3,143 counties)

Zip-code-level correlation of internet access with		Zip-code-level correlation of computer access with	
Total disability rate	-0.3873	Total disability rate	-0.4040
Ambulatory disability rate	-0.2352	Ambulatory disability rate	-0.2320
Cognitive disability rat	-0.2222	Cognitive disability rate	-0.2261
Uninsurance rate, total population	-0.3342	Uninsurance rate, total population	-0.2602
Uninsurance rate, children <18	-0.1621	Uninsurance rate, children <18	-0.1412
Uninsurance rate, adults 18-6	-0.3890	Uninsurance rate, adults 18-64	-0.3166
Ethnic minority population (%)	-0.1779	Ethnic minority population (%)	-0.1356
Poverty rate	-0.4486	Poverty rate	-0.3938
College degree or higher (%)	0.5290	College degree or higher (%)	0.4870
Unemployment rate	-0.2329	Unemployment rate	-0.2093
County-level correlation of internet access with		**County-level correlation of computer access with**	
Total disability rate	-0.7002	Total disability rate	-0.7102
Ambulatory disability Rate	-0.7478	Ambulatory disability Rate	-0.7568
Cognitive disability Rate	-0.6442	Cognitive disability Rate	-0.6434
Life expectancy	0.6883	Life expectancy	0.6658
All-cause mortality rate	-0.6815	All-cause mortality rate	-0.6607
Cardiovascular disease mortality rate	-0.6795	Cardiovascular disease mortality rate	-0.6508
Cancer mortality rate	-0.5703	Cancer mortality rate	-0.5843
Diabetes mortality rate	-0.5555	Diabetes mortality rate	-0.5337
Homicide rate	-0.5869	Homicide rate	-0.5425
Suicide rate	-0.2732	Suicide rate	-0.2423
Self-assessed fair/poor health, adults (%)	-0.7209	Self-assessed fair/poor health, adults (%)	-0.6557
Mental distress, adults (%)	-0.3013	Mental distress, adults (%)	-0.2851
Current smoking rate	-0.6589	Current smoking rate	-0.6475
Physical inactivity rate	-0.6583	Physical inactivity rate	-0.6565
Obesity rate	-0.6094	Obesity rate	-0.5864
Hospitalization rate	-0.5440	Hospitalization rate	-0.5672
Uninsurance rate, total population	-0.3901	Uninsurance rate, total population	-0.2652
Uninsurance rate, children <18	-0.2585	Uninsurance rate, children <18	-0.1675
Uninsurance rate, adults 18-64	-0.4543	Uninsurance rate, adults 18-64	-0.3331
Ethnic minority population (%)	-0.2942	Ethnic minority population (%)	-0.2492
Poverty rate	-0.7212	Poverty rate	-0.6492
College degree or higher (%)	0.7371	College degree or higher (%)	0.7133
Unemployment rate	-0.4229	Unemployment rate	-0.4054

Source: Data derived from the 2013-2017 American Community Survey; National Mortality Database; and County Health Rankings and Roadmaps p-values were <0.001.

3. Results

3.1. Racial/Ethnic and Socioeconomic Disparities in Broadband Internet and Computer Use

For the total US population in 2017, 94.2% had a computer, which includes smartphones, and 82.9% used a broadband internet subscription. Despite high levels of overall access, there were significant disparities in computer and internet use by sociodemographic characteristics. In 2017, persons aged 65 and older were less likely to have access to computer and broadband internet

Table 4: Life expectancy, age-adjusted all-cause and cause-specific mortality rates, morbidity, disability, health-risk behaviors, and health insurance rates by internet and computer use quintiles, United States, 2013-2017 (N = 3,143 counties)

Percentage of Households with an Internet Subscription							
Indicators	**Q1 (<62.31)**	**Q2 (62.31–71.30)**	**Q3 (71.31–77.90)**	**Q4 (77.91–85.20)**	**Q5 (>85.20)**	**Absolute Disparity (Q1-Q5)**	**Rate Ratio (Q1/Q5)**
Life expectancy at birth (years)	75.18	76.27	78.07	79.71	81.78	-6.60	0.92
All-cause mortality rate	928.51	874.67	781.78	0.36	615.82	312.69	1.51
Cardiovascular disease mortality rate	289.51	271.55	237.41	210.72	181.69	107.82	1.59
Cancer mortality rate	181.64	178.80	165.45	153.83	140.48	41.15	1.29
Diabetes mortality rate	34.60	27.67	23.61	20.28	16.09	18.50	2.15
Suicide rate	17.45	14.97	14.05	13.07	11.46	5.99	1.52
Homicide rate	13.83	13.51	8.36	5.74	2.73	11.10	5.06
Total disability rate	18.46	16.58	13.86	11.87	9.43	9.03	1.96
Cognitive disability Rate	7.40	6.66	5.55	4.79	3.72	3.68	1.99
Ambulatory disability Rate	11.30	9.80	7.82	6.50	4.87	6.44	2.32
Uninsurance rate	15.81	12.46	11.26	10.40	7.80	8.01	2.03
Hospitalization rate	72.06	61.26	51.38	45.19	39.25	32.81	1.84
Self-assessed fair/poor health, adults (%)	23.78	20.23	17.89	15.70	12.49	11.29	1.90
Mental distress, adults (%)	14.75	13.37	12.42	11.47	9.96	4.78	1.48
Current smoking rate	20.95	19.37	17.12	14.93	12.29	8.67	1.71
Obesity rate	34.24	33.04	30.05	26.96	23.89	10.35	1.43
Physical inactivity rate	31.26	28.67	25.41	21.93	18.36	12.90	1.70
Percentage of Households with One or More Computing Device							
Indicators	**Q1 (<75.21)**	**Q2 (75.21– 82.10)**	**Q3 (82.11–87.10)**	**Q4 (87.11–92.10)**	**Q5 (>92.10)**	**Absolute Disparity (Q1-Q5)**	**Rate Ratio (Q1/Q5)**
Life expectancy at birth (years)	75.10	76.26	78.25	79.87	81.80	-6.70	0.92
All-cause mortality rate	933.18	876.62	772.13	697.56	614.88	318.30	1.52
Cardiovascular disease mortality rate	287.21	268.34	234.94	210.42	178.76	108.46	1.61
Cancer mortality rate	183.66	178.96	165.13	153.12	137.68	45.99	1.33
Diabetes mortality rate	34.92	27.68	23.04	19.78	16.93	17.99	2.06
Suicide rate	17.52	16.00	13.58	12.67	12.32	5.20	1.42
Homicide rate	13.09	12.81	8.36	5.37	3.10	9.99	4.23
Total disability rate	18.73	16.90	13.77	11.59	9.27	9.46	2.02
Cognitive disability Rate	7.51	6.70	5.53	4.64	3.75	3.76	2.00
Ambulatory disability Rate	11.52	9.87	7.80	6.33	4.74	6.79	2.43
Uninsurance rate	15.35	12.05	10.22	10.53	8.86	6.49	1.73
Hospitalization rate	74.27	62.26	51.33	45.02	36.53	37.74	2.03
Self-assessed fair/poor health, adults (%)	23.84	19.45	17.63	15.59	12.59	11.25	1.89
Mental distress, adults (%)	14.58	13.31	12.24	11.40	10.00	4.58	1.46
Current smoking rate	21.17	19.27	17.10	14.66	12.12	9.05	1.75
Obesity rate	34.49	32.99	29.88	26.64	23.90	10.60	1.44
Physical inactivity rate	31.00	28.72	25.36	21.70	17.70	13.30	1.75

Data derived from the 2013-2017 American Community Survey; National Mortality Database; and County Health Rankings and Roadmaps. Q1 through Q5 represent first through fifth quintiles. Mortality rates are per 100,000 population. The hospital admission rate is preventable hospital stays for ambulatory care sensitive conditions per 1,000 Medicare enrollees. All p_{trend} were <0.001. All rate differences and rate ratios were statistically significant at p <0.001.

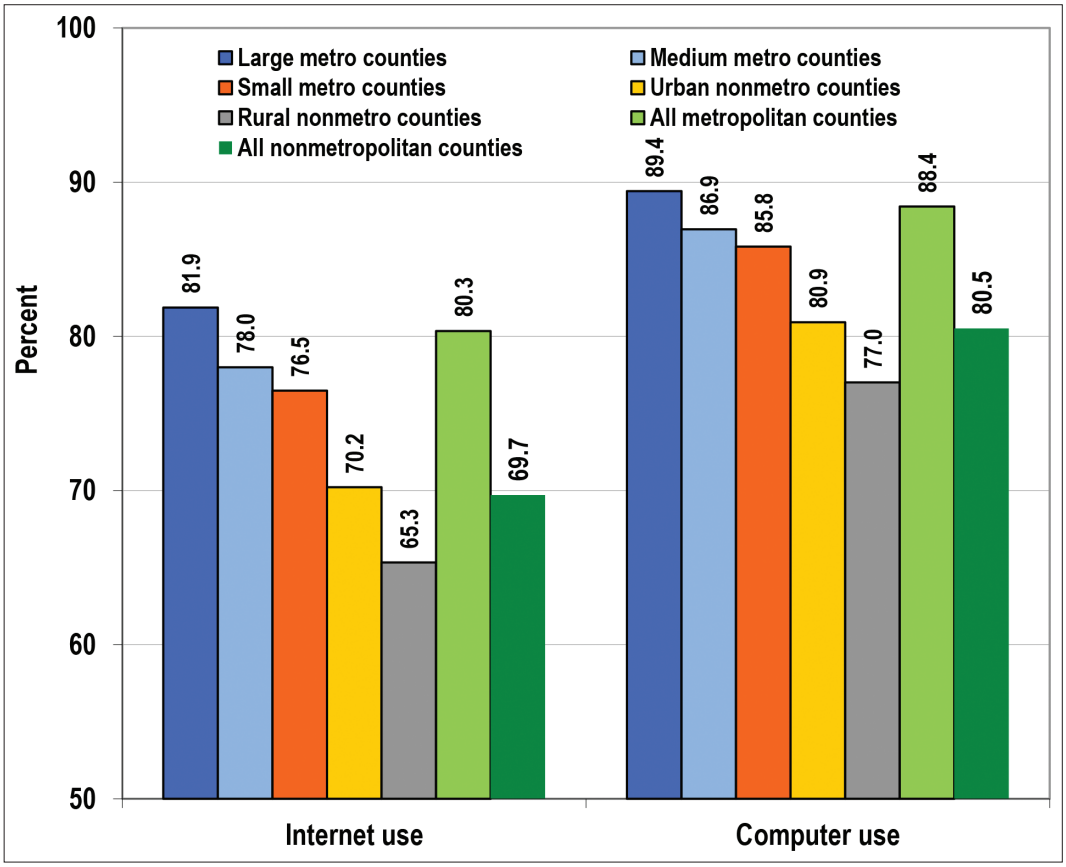

Figure 3: Internet and Computer Use Among US Adults Aged ≥18 years by Levels of Urbanization, (2013 Rural-Urban Continuum Code), United States, 2013-2017

Source: Data derived from the 2013-2017 American Community Survey.

Gradients in internet and computer use by level of urbanization were statistically significant at p<0.001.

Metropolitan (urban) counties include: (1) large metro = counties in metropolitan areas of ≥1 million population, (2) medium metro = counties in metropolitan areas of 250,000-999,999 population, (3) small metro = counties in metropolitan areas of <250,000 population.

Nonmetropolitan (rural) counties include: (4) urban nonmetropolitan counties or small urban towns = population 2,500 to 49,999, (5) nonmetropolitan rural counties or small rural towns with a population of <2,500.

than those younger than age 65 (Table 1). Approximately 82.7% of persons aged 18-24 had access to broadband internet, compared with 80.5% among those aged ≥65. Approximately 97.8% of persons aged 18-24 reported computer use, compared with 82.8% of those aged ≥65. After controlling for sociodemographic characteristics, persons aged 18-24 had 1.7 times higher odds of broadband internet use and 19.8 times higher odds of computer use, compared with those aged ≥65.

In 2017, 89.7% of APIs had broadband internet service, compared with 66.0% of AIANs, 77.2% of Blacks, 78.8% of Hispanics, and 83.5% of non-Hispanic Whites. APIs (97.4%) were more likely and AIANs (80.3%) less likely than other racial/ethnic groups to own or use a computer (including smartphones). After controlling for sociodemographic characteristics in the multivariate logistic regression models, APIs had 38% higher odds of broadband internet use and 51% higher odds of computer use, compared with non-Hispanic Whites. AIANs, Blacks,

and Hispanics had significantly lower adjusted odds of broadband internet and computer use than their non-Hispanic White counterparts (Table 1).

Education and income/poverty level were strongly and consistently linked to both broadband internet and computer use. In 2017, persons with less than a high school education were significantly less likely to have a broadband service than those with a college degree (72.3% vs 89.7%). Persons with less than a high school education were significantly less likely to own or use a computer than those with a college degree (80.5% vs 98.1%). Persons below the poverty level reported significantly lower broadband internet use (72.9% vs. 88.6%) and computer use (83.7% vs. 98.2%), compared with those with incomes at or above 500% of the poverty threshold. After controlling for sociodemographic characteristics, persons with less than a high school education had, respectively, 59% and 82% lower odds of internet and computer use than those with a college degree. Persons below the poverty level had, respectively, 52% and 78% lower adjusted odds of internet and computer use than those with incomes at or above 500% of the poverty threshold.

3.2. Disparities in Disability and Health Insurance by Broadband Internet and Computer Use

Table 2 shows disparities in the prevalence of various types of disability and health insurance coverage by internet and computer use. In 2017, persons without broadband internet access were 1.34 times more likely to have a disability than those with access (17.4% vs. 13.0%). Persons who did not own or use a computer were 2.8 times more likely to have a disability than those using a computer (39.7% vs. 14.2%). Controlling for sociodemographic characteristics accounted for most of the excess risk of overall and different types of disability among those without broadband access. However, after controlling for sociodemographic characteristics, compared to those with a computer, persons who did not own or use a computer had 42% higher odds of overall disability, 43% higher odds of mental disability, 32% higher odds of ambulatory disability, 51% higher odds of self-care disability, 42% higher odds of independent living disability, 32% higher odds of hearing disability, and 36% higher odds of vision disability.

In 2017, persons without broadband access were 77% more likely to be without health insurance than those with access (11.4% vs. 6.5%). Persons who did not own or use a computer were 30% more likely to lack health insurance than those using a computer (10.0% vs. 7.8%). After controlling for sociodemographic characteristics, those lacking access to broadband internet and computers had, respectively, 29% and 11% higher odds of uninsurance than their counterparts with broadband and computer access.

3.3. Area-Level Associations between Internet and Computer Use and Health, Mortality and Socioeconomic Indicators

During 2013-2017, there were marked geographic disparities in computer and internet use, with many Zip codes in the Southeast, Southwest, Appalachia, Upper Midwest, and the rural US having lower access to computer and broadband internet (Figure 1). Similar geographic patterns were observed for county-level data (data not shown). Geographic disparities in rates of overall disability and cognitive/mental disability were also marked, with many ZIP codes in the Southeastern and Appalachian regions showing high rates (Figure 2).

Zip-code-level correlations indicate statistically significant associations between internet and computer use and various health and mortality indicators (Table 3). Zip-code areas with low internet and computer use had substantially higher rates of disability, uninsurance, ethnic minority population, poverty and unemployment, and lower education. Similar, albeit stronger correlations, were observed at the county level. Internet access and computer use was positively associated with life expectancy (γ=>0.66) and inversely associated with disability (γ=>0.70).

During 2013-2017, communities with low internet use (<62.3%) had 6.6 years shorter life expectancy than communities with high internet use (>85.2%) [75.2 years vs. 81.8%]. The corresponding difference in life expectancy associated with low

vs. high computer use was 6.7 years. Communities with lower internet and computer use also had substantially higher rates of all-cause mortality, CVD mortality, cancer mortality, diabetes mortality, homicide, suicide, self-assessed fair/poor health, mental distress, disability, preventable hospitalization, uninsurance, smoking, obesity, and physical inactivity (Table 4).

3.4. Rural-Urban Disparities in Internet and Computer Use

Figure 3 shows rural-urban disparities in internet and computer use during 2013-2017. Compared to metropolitan areas, nonmetropolitan areas had lower internet access (80.3% vs. 69.7%) and computer use (88.4% vs. 80.5%). Consistent rural-urban gradients were observed, with people in rural areas and small urban towns having the lowest level of internet use (65.3% and 70.2% respectively) and computer use (77.0 and 80.9% respectively) and those in large metropolitan areas and medium-size metropolitan areas reporting the highest level of internet use (81.9% and 78.0% respectively) and computer use (89.4 and 86.9% respectively).

4. Discussion

Although racial/ethnic and socioeconomic disparities in computer and internet use in the US have been reported previously,[1] our study shows marked disparities in access and use by a broad set of social determinants including age, gender, race/ethnicity, nativity/immigrant status, marital status, education, income, employment status, housing tenure, geographic region, and rural-urban residence. Our study is one of the first to examine a wide range of health disparities among people and communities lacking access to broadband internet and computers. The study findings indicate startling gaps in broadband internet and computer use and related health inequalities. During 2013-2017, more than 30% of the rural population (or 46 million people) lacked access to broadband internet and 20% did not own or use computers. For people in smaller rural communities that make up more than one-fifth of all US counties, these percentages were even higher. In 2017, 316,882 (34%) AIAN adults aged ≥18, 5.1 million (23%) Black/African-American adults, and 7.2 million (21%) Hispanic adults lacked access to broadband internet. Approximately 5.7 million (27%) adults with less than a highschool education or living in poverty did not have access to broadband internet. Disparities in computer use were also striking, with 10 million White adults, 3 million Black adults, 2.6 million Hispanic adults, 2.5 million immigrants, and 5 million low-education or low-income adults not owning or using a computer.

Our findings also reveal that individuals and communities with little or no broadband access and computer use experience substantial health disparities in terms of lower life expectancy, higher mortality from chronic diseases and injuries, higher rates of poor physical and mental health, disability, hospitalization, obesity, smoking, physical inactivity, and lower access to health care. This study is a significant contribution to the research literature on digital health as such wide range of health inequalities had not been previously examined in the US, to the best of our knowledge.

Currently, 76 percent of US hospitals connect with patients and consulting practitioners through digital health technology such as video and other technology.[15] Recent census data also show that racial/ethnic minorities such as Asians, Hispanics, and Blacks are on par with or exceed Whites in their use of mobile phones.[1] As the rate of technology use in health care delivery continues to grow at a rapid pace, there are high hopes and expectations for telehealth to also aid in the reduction of health disparities, including those in patient outcomes, cost, and access to care.

With more than half of US hospitals having already implemented telehealth capabilities, the growing hype around the efficiency of care it offers both patient and provider, doesn't seem to be dying down any time soon.[15] Telehealth services also offer providers alternatives to patient care, thus reducing physician burnout due to driving time to and from the office and increasing time spent with patients.[15] The merging of the internet and health also allows for a more efficient use of time and resources for many health care providers. For example, there is the

enhanced potential for data to be shared amongst providers more rapidly.[16]

In addition, telehealth allows for there to be less of a risk of disease transmission amongst patients waiting to be seen at the provider's office. Most recently, the promotion of telehealth has increased due to the COVID-19 crisis and subsequent mandates for social distancing. One of the many global impacts of this pandemic has left many minority populations and vulnerable communities with an increased lack of resources and access. As many health offices are closed and hospitals have shifted focus to testing and treating Coronavirus patients, patients seeking care or treatment services outside of those parameters, such as for prescription changes or refills, are asked to utilize telehealth.

Overall, technology can play a critical role in reducing health inequities and can help in both the mobilizing and centralizing of communication with health care workers and their patients. However, the potential challenges that may present as we aim to fill the gap of the digital divide should also be considered. Some unanticipated consequences may include ensuring that different racial/ethnic populations are utilizing internet at the same rate as others; that all research and data are accessible to all populations; and that personal interactions between provider and patient do not become extinct as technology becomes more prominent in health care. Finally, although barriers to the adoption of digital health technologies may be present, early research shows that it is outweighed by its benefits and revolutionizing potential.[17]

4.1. Limitations

This study has limitations. Our study provides only limited analysis of health and health care disparities at the individual level for those lacking access to broadband internet and computers. In the ACS microdata sample, presence of a disability and whether or not individuals had access to health insurance were the only two health-related variables available. No information was available regarding chronic conditions, poor physical health, mental distress, hospitalization, affordability of health care costs, patient-provider communication, difficulty in obtaining health care due to transportation, satisfaction with health care, smoking, obesity, and physical inactivity among individuals without broadband and computer access. Although we analyzed many of these health outcomes at the community level, the patterns of disparities in these outcomes associated with lack of internet and computer access may differ from those at the individual level.

Another potential limitation of the study is that it cannot account for all racial/ethnic and socioeconomic gaps related to the uptake of health care technology. In addition, the study does not address the potential negative health outcomes due to utilizing telehealth. For example, a patient may require in person care and risks being misdiagnosed or the severity of their health issue negated.

5. Conclusions and Implications for Translation

Despite high levels of internet and computer use in the US, significant socioeconomic and racial/ethnic disparities in use of digital technology and related health disparities exist. Risks of various types of disabilities and lack of health insurance are greater among individuals with lower broadband internet and computer access. Communities with reduced internet and computer access have lower life expectancy and are at substantially increased risks of mortality from various chronic conditions, poor health, mental distress, preventable hospitalization, smoking, obesity, and physical inactivity. Closing the social divide in broadband internet and computer use can positively impact individual empowerment, educational attainment, economic growth, community development, access to health care and health-related information, and health promotions efforts.

Compliance with Ethical Standards

Financial Disclosure*: None to report.* ***Funding/ Support****: None.* ***Conflicts of Interest****: None.* ***Acknowledgment:*** *None.* ***Disclaimer:*** *The views expressed are the authors' and not necessarily those*

of the US Department of Health and Human Services or the Health Resources and Services Administration. ***Ethical approval:*** *This study used existing de-identified publicly available data and was deemed exempt.*

Key Messages

- There are startling gaps in broadband internet and computer use and related health inequalities in the United States.
- Communities with low internet and computer use have seven years shorter life expectancy than communities with high use and are at substantially increased risks of mortality from various chronic conditions, poor physical and mental health, disability, hospitalization, smoking, obesity, physical inactivity, and reduced access to care.
- More than a quarter million (or 34%) AIAN adults, 5.1 million (23%) Blacks/African-Americans, and 7.2 million (21%) Hispanics lacked access to broadband internet in 2017. Approximately 5.7 million (27%) adults with less than a high school education or living in poverty did not have broadband internet access.
- More than 30% of the rural population (or 46 million people) lacked access to broadband internet and 20% did not own or use computers during 2013-2017. Lack of broadband internet access is particularly acute in small rural towns of America.
- Increased broadband internet and computer access offers a more efficient way for providers to care for patients while also aiding in the reduction of health disparities by presenting vulnerable populations and communities increased opportunities for education, employment, health care access, and health-related information.

References

1. Ryan C. *Computer and Internet Use in the United States: 2016*. American Community Survey Reports. Washington, DC: US Census Bureau; 2018.
2. Bresnick J. AMIA: consider broadband access as a social determinant of health. Health IT Analytics: Population Health News. https://healthitanalytics.com/news/amia-consider-broadband-access-a-social-determinate-of-health. Published May 25, 2017. Accessed April 20, 2020.
3. National Academies of Sciences, Engineering, and Medicine. *The Promises and Perils of Digital Strategies in Achieving Health Equity. Workshop Summary*. Washington, DC: The National Academies Press; 2016. https://doi.org/10.17226/23439
4. Lewis JM. Internet access and racial/ethnic disparities in using internet health resources. SEHSD working paper 2017-31. US Census Bureau. https://www.census.gov/content/dam/Census/library/working-papers/2017/demo/SEHSD-WP2017-31paper.pdf. Published June 2017. Accessed April 20, 2020.
5. Kochanek KD, Murphy SL, Xu J, Arias E. Deaths: final data for 2017. *Natl Vital Stat Rep*. 2019; 68(9):1-77.
6. *Health, United States, 2017: With Special Feature on Mortality*. National Center for Health Statistics; 2018.
7. US Census Bureau. *The 2017 American Community Survey*; 2018. https://www.census.gov/programs-surveys/acs/. Accessed April 20, 2020.
8. US Census Bureau. *The 2017 ACS PUMS Data Dictionary*; 2018. https://www2.census.gov/programs-surveys/acs/tech_docs/pums/data_dict/PUMS_Data_Dictionary_2017.pdf. Accessed April 20, 2020.
9. US Census Bureau. *American Community Survey and Puerto Rico Community Survey: 2017 Subject Definitions*; 2018. https://assets.nhgis.org/original-data/acs/2017_ACSSubjectDefinitions.pdf. Accessed April 20, 2020.
10. US Census Bureau. *The 2013-2017 5-Year ACS Summary File*; 2018. https://www2.census.gov/programs-surveys/acs/summary_file/2017/data/?#. Accessed April 20, 2020.
11. Robert Wood Johnson Foundation. County Health Rankings & Roadmaps; 2019. https://www.countyhealthrankings.org/. Accessed April 20, 2020.
12. Singh GK, Lin SC. Marked ethnic, nativity, and socioeconomic disparities in disability and health insurance among US children and adults: the 2008-2010 American community survey. *Biomed Res Int.* 2013;2013:627412. doi: 10.1155/2013/627412
13. Singh GK, Daus GP, Allender M, et al. Social determinants of health in the United States: addressing major health inequality trends for the nation, 1935-2016. *Int J MCH AIDS*. 2017; 6(2):139-164. doi: 10.21106/ijma.236

14. SAS Institute Inc 2013. SAS/ACCESS® 9.4 Interface to ADABAS: Reference. Cary, NC: SAS Institute Inc.

15. American Hospital Association. *Fact Sheet: Telehealth*. Chicago, IL; 2020; https://www.aha.org/factsheet/telehealth. Accessed April 20, 2020.

16. Eysenbach G. What is e-health? *J Med Internet Res*. 2001;3(2):e20. doi: 10.2196/jmir.3.2.e20

17. Cohen AB, Safavi K. The oversell and undersell of digital health. Health Affairs Forefront. https://www.healthaffairs.org/do/10.1377/hblog20190226.63748/full/. Published February 27, 2019. Accessed April 20, 2020.