

1 Updated estimates of comorbidities associated with risk for COVID-19 complications based on
2 US data

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9 Abstract (149 words)

10 We updated previous estimates (wwwnc.cdc.gov/eid/article/26/8/20-0679_article) of adults with
11 any underlying condition increasing risk of complications from COVID-19 using recent US
12 hospitalization data instead of mortality data from China. This substitutes obesity for cancer in
13 the definition and increased the percentage of adults reporting ≥ 1 condition to 56.0% (95% CI
14 55.7-56.4). When controlled for all measures listed, factors increasing odds of reporting any of
15 the underlying conditions include being male, older, African American, American Indian,
16 household income $< \$25,000$, $<$ high school education, underinsurance, living in the South or
17 Midwest (vs. West), plus the risk factors of ever smoking, sedentary lifestyle, and inadequate
18 fruit and vegetable consumption. Population-attributable risk for the listed risk factors was
19 13.0%, 12.6%, and 15.0% respectively. Results have potential implications for policies based on
20 risk-stratification of the population and for improvement of risk status through lifestyle change.
21 National support for a “health promotion” campaign would be timely.

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26 One of the novel aspects of the current coronavirus pandemic is that information is
27 constantly being updated as more studies are published. We had earlier reported estimates of
28 comorbidities affecting risk for complications from COVID-19 that were based on mortality data
29 from China (1). Newly released US data on hospitalizations for COVID-19 from 14 states
30 indicate a slightly different list of conditions affecting risk, with obesity added and cancer
31 subtracted (2). Those preliminary results indicate that 89% of those hospitalized for COVID-19
32 had an underlying condition, the most common being hypertension, obesity, chronic lung disease
33 (including asthma and chronic obstructive pulmonary disease), diabetes, and cardiovascular
34 disease (2). Similar results were found for ICU admissions on a smaller sample and without
35 obesity (3). The Guidelines for Opening up America Again released by the White House on
36 April 16, 2020 (4) include a similar list to define vulnerable individuals, except that list includes
37 elderly (undefined) and those with a compromised immune system and omits cardiovascular
38 disease.

39 Our main objective for this study was to use population based US data to estimate the
40 fraction of adults in the community who might be a risk of hospitalization for COVID-19 (2) due
41 to reporting any of the most common underlying conditions listed above. Secondly, we sought
42 to determine the demographic and risk factors that increased the likelihood of having one or
43 more of these underlying conditions. And thirdly, using the information about potentially
44 modifiable risk factors obtained through our second objective, we estimated population
45 attributable-risk for conditions increasing risk for COVID-19 hospitalization.

46

47 Methods

48 We used publicly available 2017 Behavioral Risk Factor Surveillance System (BRFSS)
49 data (5) from telephone surveys of 444,649 randomly selected adults ages 18 and older in the 50
50 states and the District of Columbia (DC). The BRFSS includes only non-institutionalized adults
51 so residents of prisons, nursing homes and assisted living facilities are among those not
52 surveyed. We chose to use 2017 data in order to include hypertension which was not addressed
53 in 2018. Data were adjusted for the probability of selection and weighted to be representative of
54 the adult population in each state by age, gender, race/ethnicity, marital status, education, home
55 ownership, and telephone type and included weights and stratum variables needed for analysis.
56 Results were not age adjusted in order to reflect the age distribution of each state rather than a
57 standard population. The median response rate for cell phone and land line surveys combined
58 was 47.2%, ranging from 33.9% in California to 61.1% in Utah (6). Reliability and validity of
59 the BRFSS have been found to be moderate to high for many survey measures, in particular
60 those used here which can be checked versus medical records (7).

61 The key variable was a composite measure including adults reporting they were ever told
62 they had diabetes (excluding if only when pregnant), asthma (and still had it), chronic obstructive
63 pulmonary disease (COPD), hypertension, cardiovascular disease (CVD; ever told they had a
64 heart attack, angina, coronary heart disease, or a stroke) or they were obese with body mass
65 index ≥ 30.0 based on self-reported height and weight. The number of conditions was counted for
66 each respondent and adults who reported at least one were considered to be at risk of
67 hospitalization due to an underlying condition. Risk factors included ever smoking 100
68 cigarettes, sedentary lifestyle, defined as no leisure time physical activity in the past month, and
69 inadequate fruit and vegetable consumption, defined as consuming the combination < 5 times per
70 day based on responses to five separate questions, with responses to the question about fried

71 potatoes or French fries excluded. A composite measure was also created for risk factors by
72 counting the number for each respondent and determining those with each number of risks from
73 0-3.

74 Demographic measures included age group (18-29, 30-39, 40-49, 50-59, 60-69, 70-79, and
75 80+ years, which was created by combining 5 year age groups provided in the data set), self-
76 reported race/ethnicity (non-Hispanic white, Black or African American, Hispanic of any race,
77 American Indian/Alaska native, Asian/Pacific Islander, and other), less than a high school
78 education (vs. high school graduate or higher), household income < \$25,000 (vs. all other
79 incomes including unknown), being underinsured (having no health insurance coverage or
80 reporting a time in the past year when the needed health care but could not get it due to cost),
81 state of residence which included DC, whether or not they lived within the center city of a
82 Metropolitan Statistical Area (MSA), and census region (Northeast, Midwest, South, or
83 West)(8).

84
85 Stata version 14.1 (Stata Corp LP, College Station, TX) was used for analysis to account for the
86 complex sample design of the BRFSS. Point estimates and 95% confidence intervals are
87 reported using the weights, stratum, and PSU variables supplied in the data set (5). Missing
88 values were excluded from analysis. Population-attributable risk (PAR) was used to compare the
89 contributions of individual risk factors to the composite measure of any of the 6 underlying
90 conditions and to each of the 6 component conditions (9). PAR estimates take into account not
91 only the relative risk of people with that risk factor developing the outcome, but also the
92 prevalence of the risk factor in the population (10). PARs were estimated in Excel using Levin's

93 formula (11) and adjusted odds ratios (AOR) obtained from logistic regression instead of
94 unadjusted relative risk.

95 Results

96 Sample was described earlier (1). Overall, 56.0% (95% CI 55.7-56.4) of respondents had
97 one or more of the underlying conditions, ranging from 33.7% among 18-29 year olds to 79.1%
98 for those 80 years and older. Prevalence rates of the separate conditions were 8.5% for CVD,
99 6.6% for COPD, 9.1% for asthma, 10.8% for diabetes, 32.4% for hypertension, and 30.1% for
100 obesity. While the percentage of adults with any of the conditions increased with age (Table 1),
101 60.7% of the total was younger than age 60. Rates also varied by all the measures in Table 1
102 except underinsurance. State rates ranged from 45.6% in DC to 68.8% in West Virginia. Using
103 the definition for vulnerable individuals according to the Guidelines for Opening up America
104 (4) which adds age (we used age 65 as elderly) and removes CVD, that prevalence rate is 60.4%
105 (95% CI 60.0-60.7).

106 Prevalence rates for the risk factors used in PAR estimates for all ages were 40.4% for ever
107 smoking, 26.6% for sedentary lifestyle, and 84.1% for inadequate fruit and vegetable
108 consumption. Among ever smokers of all ages, 40.7% currently smoke, including 50.6% of those
109 ages 18-59 and 22.8% of adults ages 60 and older. Those estimates result in current smoking
110 rates of 16.5%, 18.6%, and 11.2% respectively.

111 Results of multiple logistic regression controlled for age, gender, education, income,
112 race/ethnicity, underinsurance, region, and the 3 behavioral risk factors (Table 2) indicate that
113 male gender, increasing age, less education and income, being underinsured, having each of the
114 risk factors, being African American, or American Indian/Alaska Native and living in either the

115 Midwest or South significantly increased the odds of having an underlying condition shown to be
116 associated with COVID-19 hospitalizations. Hispanic ethnicity had no effect while being
117 Asian/Pacific Islander decreased the odds of having any of the conditions. Adding a variable for
118 living in the center city of an MSA had no effect when controlled for the other measures.
119 Including the composite risk factor measure in the logistic regression model in place of the
120 separate risks confirmed the step-wise increase with an AOR of 2.56 (2.38-2.76) for adults with
121 all 3 risk factors compared with those reporting none.

122 PAR estimates for the 3 potentially modifiable risk factors, estimated using the AORs in
123 Table 2 are shown in Table 3. Among all adults, these 3 risk factors were estimated to account
124 for 40.6% of the total risk of any underlying condition, 34.2% of total risk for adults 18-59 and
125 59.7% of total risk for adults age 60 and older. The total attributable risk for all adults for the
126 separate conditions ranged from 18.7% for asthma to 69.2% for COPD. (Table 3).

127 Discussion

128 We estimate that 56.0% of US adults, with a wide range across age groups and states, have
129 one or more underlying conditions that increase risk of hospitalization due to COVID-19. Our
130 previous definition of adults at risk of complications from COVID-19 (1) that excluded obesity
131 and added cancer based on data for China where obesity is much less prevalent (13) resulted in
132 an estimate of 45.4%. Using the definition of vulnerable individuals in the White House
133 Guidelines (4) resulted in an estimate for those at risk of 60.4%. Thus, except for measures that
134 exclude obesity, it appears that over 50% of all adults are at risk for hospitalization or can be
135 considered vulnerable individuals. In addition, while rates increase with increasing age group
136 and age is the key predictor of reporting an underlying condition, over half of adults with

137 underlying conditions using *any* of these definitions are < 60 years. Although our definition of
138 underlying conditions does not include every condition reported among the 89% of persons
139 hospitalized for COVID-19 (2) who reported any, our population based prevalence of 56% for
140 any of the conditions is consistent with any of these 6 conditions increasing risk for
141 hospitalization. The underlying chronic conditions increasing risk for COVID-19 hospitalizations
142 are also very similar to those increasing risk for seasonal influenza complications (14).

143 All the underlying conditions used in our measures are conditions for which behavioral risk
144 factors have been well established (9, 12). Our list of underlying conditions includes obesity,
145 diabetes, and hypertension, which are also considered risk factors in some studies (9, 12). Causal
146 relationships between risk factors and outcomes can be complicated; for example, previous
147 results (9) have shown that obesity contributes 37.8% to attributable-risk for diabetes, 30.9% to
148 hypertension and 16.4% to asthma, while hypertension and diabetes contribute 29.3% and 6.7%
149 respectively to CVD. For simplification, we limited our list of risk factors to lifetime smoking,
150 sedentary lifestyle, and inadequate fruit and vegetable consumption. Each selected risk factor
151 was associated with increased likelihood of reporting any of the 6 underlying conditions with
152 AORs of 1.21 to 1.54. In addition, the unadjusted results for increasing number of risk factors
153 indicate a step-wise increase in the percentage of adults reporting any of the underlying
154 conditions with each additional risk factor as shown in Table 1. This result was confirmed by
155 logistic regression and provides new and informative data on factors that predict increased
156 likelihood of reporting any of the underlying conditions.

157 The results on the risk factors suggest the impact is consequential, with total PARs for the 3
158 risk factors of 40.6% overall, 34.2% for adults 18-59 and 59.7% for adults ages 60 and older. Of
159 course the smoking measure included lifetime smoking in order to capture effects among former

160 smokers, while current smoking rates are much lower at 16.5% overall. The results suggest the
161 potential for considerable improvement by reducing just these 3 risk factors, or even 2 of the 3.
162 For example, increasing fruit and vegetable consumption and initiating an exercise program such
163 as walking could potentially lower the future risk of developing any of these underlying
164 conditions, with total elimination lowering risk by as much as 46.0% for adults ages 60 and older
165 and 21.6% for those 18-59 years.

166 In addition to the risk factors mentioned above, a long list of variables increased the
167 likelihood of reporting an underlying condition when controlled for other factors. Foremost
168 among them are being older, male, and African American, all groups which preliminary
169 hospitalization data (2) suggested were disproportionately affected by COVID-19. Results from
170 this study indicate that even when controlled for age, sex, underinsurance, income, region, and
171 the 3 risk factors, men, African-Americans, and adults age 60 and older are all more likely to
172 report any of the underlying conditions increasing risk for hospitalizations, with AORs of 1.15,
173 1.67 and ≥ 4.79 respectively. Thus it appears part of the reason these groups were
174 disproportionately hospitalized for COVID-19 (2) is because they are more likely to report any
175 of the underlying conditions. More study will be needed to determine if other factors increasing
176 likelihood of underlying conditions such as less education and income, and being underinsured
177 or American Indian, are confirmed as increasing hospitalization rates among adults with
178 COVID-19.

179 In this study we grouped states into regions based on the 4 census regions (8) which clearly
180 showed that living in either the Midwest or South increased risk of reporting an underlying
181 condition compared with the West (or Northeast). This result is consistent with studies showing
182 that obesity rates are also highest in these regions (15). And while living in a city (center city of

183 an MSA) was associated with reporting an underlying condition in unadjusted analysis, once
184 controlled for demographics and risk factors, urban residence was no longer statistically
185 significant. On the other hand, underinsurance was not associated with reporting an underlying
186 condition in unadjusted analysis but was a statistically significant predictor of reporting an
187 underlying condition once controlled for all measures in the model. Underinsurance has the
188 potential to present a barrier to hospitalization for any reason.

189 Limitations

190 Our study does not address possible differences in contracting the disease, only the risk of
191 hospitalization among those with COVID-19, based on preliminary US results for underlying
192 conditions (2,3). Only non-institutionalized adults are surveyed so 1.3 million adults in nursing
193 homes (16) were excluded which almost certainly underestimates those with underlying
194 conditions who are included in hospitalization data. Data are self-reported and reliability and
195 validity can vary for different measures tested (7). But as long as a respondent was told they had
196 a chronic condition, validity was high. The variable for living in the center city of an MSA was
197 missing for a large number of respondents. Reverse causality may be a factor in some of the PAR
198 estimates, especially for sedentary lifestyle. Age groups used for analysis did not match those
199 used for weighting data but that should have a minimal effect on results. Low response rates
200 could introduce bias but, as noted, validity appears high for the measures used in this study. A
201 dearth of denominator data addressing the actual prevalence of coronavirus infection and
202 immunity in the United States makes it difficult to draw reliable conclusions about overall rates
203 of hospitalization or death among those exposed.

204 Conclusion: We estimate 56.0% of US adults are at risk of needing hospitalization for COVID-
205 19 due to underlying conditions. Such estimates will vary depending on exact criteria used to
206 define underlying conditions but represent a substantial fraction of all US adults. These
207 underlying conditions are, in turn, associated with modifiable risk factors including ever
208 smoking, being sedentary and inadequate fruit and vegetable consumption. The three risk factors
209 were estimated to contribute 40.6% of attributable-risk for all adults reporting any of the
210 underlying conditions in this study including 34.2% of attributable-risk among adults ages 18-59
211 and 59.7% for adults ages 60 and older. These results suggest the potential for policies based on
212 risk-stratification of the population and for possible improvement of risk status through lifestyle
213 change. A national focus on, and support for, a “health promotion” campaign would be timely.

214

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Table 1. Demographics of adults with any of 6 underlying conditions^a;

2017 Behavioral Risk Factor Surveillance System.

Population Group	Percent	95% CI	Sample Size
Total	56.0	55.7-56.3	398,865
Gender			
Males	56.7	56.2-57.2	183,097
Females	55.3	54.8-55.8	215,768
Age (years)			
18-29	33.7	32.9-34.5	42,434
30-39	45.0	44.2-45.9	44,676
40-49	53.6	52.7-54.5	49,449
50-59	63.4	62.6-64.1	73,839
60-69	71.4	70.8-72.1	90,088
70-79	78.8	78.0-79.6	63,627
80+	79.1	77.9-80.2	31,915
Race/ethnicity			
White (non-Hispanic)	56.7	56.3-57.0	307,282
African-American	65.8	64.7-66.8	31,939
Hispanic	52.3	51.2-53.5	26,837
American Indian/Alaska Native	67.7	65.3-70.1	7,468
Asian/Pacific Islander	34.1	32.1-36.3	9,108
Other	57.0	55.0-59.0	10,089
Education			
<High school	66.8	65.6-67.9	26,450
High school	59.6	58.9-60.2	107,876
Some college	57.2	56.5-57.8	111,267
College graduate	46.4	45.9-46.9	152,651
Household income			
< \$15,000	67.5	66.2-68.7	31,888
\$15K-\$24,999	63.6	62.7-64.6	54,891
\$25K-\$49,999	58.9	58.1-59.6	85,409
\$50K-\$74,999	55.6	54.7-56.6	55,794
\$75K+	47.9	47.3-48.5	116,138
Unknown	54.8	53.9-55.8	54,903

Census Region

Northeast	54.0	53.3-54.8	67,564
Midwest	57.4	56.9-58.0	119,303
South	58.9	58.3-59.5	122,132
West	51.6	50.8-52.4	90,056

Relation to center city of MSA

Center City	65.2	64.2-66.1	53,318
Not center city	55.1	54.7-55.5	345,737

Underinsured

Yes	56.4	55.6-57.3	58,967
No	56.0	55.6-56.4	337,892

Risk Factors

Ever smoked

Yes	64.3	63.8-64.8	170,149
No	50.5	50.0-51.0	219,779

Sedentary lifestyle

Yes	67.8	67.2-68.5	100,438
No	52.3	51.9-52.7	276,037

Eat <5 a day

Yes	57.0	56.6-57.4	300,938
No	50.0	49.0-50.9	58,286

Number of risk factors

0	42.8	41.6-44.0	31,529
1	48.9	48.4-49.5	146,808
2	62.1	61.5-62.7	133,833
3	73.2	72.3-74.1	43,147

State

AL	65.6	63.9-67.3	6,083
AK	56.5	53.4-59.5	2,961
AZ	55.5	54.4-56.6	13,824
AR	65.1	62.5-67.7	4,713
CA	50.2	48.7-51.7	8,304
CO	47.6	46.3-48.9	8,812

CT	54.0	52.5-55.4	9,302
DE	59.2	56.9-61.5	3,554
DC	45.6	43.5-47.6	4,012
FL	57.4	55.7-59.0	19,402
GA	57.3	55.5-59.1	5,247
HI	52.5	50.9-54.1	7,226
ID	53.3	51.2-55.3	4,535
IL	56.8	55.1-58.6	5,208
IN	59.7	58.5-60.9	12,676
IA	58.6	57.2-59.9	6,991
KS	58.0	57.1-58.9	19,304
KY	62.7	60.9-64.5	7,826
LA	61.9	60.0-63.9	4,328
ME	58.4	56.8-60.0	9,141
MD	56.4	55.0-57.9	12,056
MA	52.1	50.1-54.2	6,086
MI	59.4	58.1-60.6	9,863
MN	49.9	48.9-50.9	15,155
MS	63.3	61.1-65.5	4,627
MO	57.9	56.2-59.5	6,828
MT	51.4	49.5-53.3	5,409
NE	56.6	55.3-57.9	14,059
NV	55.9	53.3-58.4	3,427
NH	54.5	52.4-56.6	5,077
NJ	55.2	53.5-56.8	10,160
NM	56.1	54.3-58.0	5,908
NY	51.5	50.2-52.8	10,937
NC	59.2	57.2-61.1	4,386
ND	55.4	53.7-57.1	6,430
OH	59.4	58.0-60.8	11,138
OK	62.7	61.0-64.4	5,891
OR	54.7	53.0-56.4	4,757
PA	57.3	55.6-59.0	6,022
RI	56.9	54.8-58.9	4,987
SC	61.6	60.2-63.0	10,191
SD	55.2	52.9-57.5	6,382
TN	61.1	59.2-63.0	5,215
TX	56.5	54.5-58.4	10,972
UT	47.4	46.1-48.7	9,115
VT	54.2	52.4-56.0	5,852
VA	55.8	54.3-57.3	8,630

WA	53.6	52.4-54.8	11,694
WV	68.8	67.1-70.5	4,999
WI	55.4	53.5-57.3	5,269
WY	53.6	51.7-55.6	4,084

275 ^a Cardiovascular disease, diabetes, chronic obstructive pulmonary disease,

276 asthma, hypertension, and/or obesity.

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Table 2. Multiple logistic regression results for outcome of reporting any of 6 underlying conditions ^a; 2017 Behavioral Risk Factor Surveillance System; N=346,198.

Group	Adjusted Odds Ratio	95% CI
Females (referent)		
Males	1.15	1.12-1.19
Age 18-29 (referent)		
30-39	1.57	1.49-1.67
40-49	2.21	2.09-2.34
50-59	3.27	3.10-3.46
60-69	4.79	4.53-5.06
70-79	7.19	6.73-7.68
80+	7.01	6.34-7.76
Never smoked (referent)		
Ever smoked	1.37	1.33-1.42
Not sedentary (referent)		
Sedentary	1.54	1.48-1.60
Fruit & vegetables 5 X/day (referent)		
< 5 time/day	1.21	1.16-1.26
High school grad/GED (referent)		
Not high school graduate	1.23	1.14-1.31
Income \$25,000+ (referent)		
Income <\$25,000	1.46	1.40-1.53
Not underinsured (referent)		
Underinsured	1.11	1.06-1.16
White non-Hispanic (referent)		
African American	1.67	1.57-1.76
Hispanic any race	1.03	0.97-1.10
American Indian/AK Native	1.67	1.46-1.92
Asian/Pacific Islander	0.57	0.51-0.63
Other	1.27	1.15-1.40
West region (referent)		
Northeast	0.98	0.94-1.03
Midwest	1.14	1.09-1.19
South	1.13	1.08-1.19

278 ^a Cardiovascular disease, diabetes, chronic obstructive pulmonary disease,

279 asthma, hypertension, and/or obesity.

Table 3. Population attributable-risk (PAR) for selected outcomes.

2017 Behavioral Risk Factor Surveillance System; Maximum N=372,041

Outcome	PAR	PAR	PAR	Sum of PARs
	Ever smoked	Sedentary lifestyle	Fruits/vegetables < 5X/day	
Any of 6 conditions ^a all adults	13.0%	12.6%	15.0%	40.6%
Any of 6 conditions ^a age <60	12.6%	9.8%	11.8%	34.2%
Any of 6 conditions ^a age 60+	13.6%	21.6%	24.4%	59.7%
Diabetes	5.0%	11.5%	15.6%	32.1%
Hypertension	8.5%	8.5%	13.1%	30.2%
COPD	52.5%	16.6%	0.0%	69.2%
Asthma	11.8%	6.9%	0.0%	18.7%
CVD	22.3%	8.7%	0.0%	31.0%
Obesity	0.0%	14.5%	13.8%	28.3%

280

281 Abbreviations: PAR: population attributable risk; COPD: chronic obstructive pulmonary disease; CVD: cardiovascular disease.

282 ^a Cardiovascular disease, diabetes, chronic obstructive pulmonary disease, asthma, hypertension, and/or obesity, conditions

283 found to be associated with US hospitalizations for COVID-19.