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The impact of key modifiable risk factors on leading chronic conditions

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ABSTRACT

We studied associations between 7 cardiovascular disease (CVD) risk factors (RFs) and 9 chronic conditions and estimated population-attributable risk. Data (N = 358,218) were from the 2017 Behavioral Risk Factor Surveillance System. Outcomes included asthma, arthritis, chronic obstructive pulmonary disease (COPD), cognitive impairment, CVD, and kidney disease. Risk factors (RF) were obesity, ever smoking, sedentary lifestyle, and inadequate fruit and vegetable consumption, while hypertension, high cholesterol, and diabetes were considered in both categories. Stata was used to study associations in both unadjusted and adjusted analysis. Population-attributable risk was estimated in Excel using adjusted odds ratios (AORs) and compared results using all RFs versus only those where causality was confirmed by other studies. RF prevalence rates ranged from 10.8% (95% CI 10.6, 11.0) for diabetes to 84.1% (83.8, 84.3) for inadequate fruit and vegetable consumption. Almost all adults (95.2%) reported ≥1 RF. Highest total PARs for RFs with confirmed causality were for obesity and ever smoking, and for hypertension when all RFs were considered. Total PARs for the 9 outcomes averaged 37.2–41.5% when results were limited to RFs with confirmed causality. Although the number of risk factors for which causality had been confirmed ranged from 1 to 6, all 9 outcomes showed linear dose response gradients with added risk factors. While all 7 RFs appeared important to address, targeting smoking and obesity with programs that have shown previous success offers the greatest potential for reducing burden for these 9 chronic diseases.

1. Introduction[1]

Potentially modifiable risk factors (RFs) such as smoking, sedentary lifestyle, and hypertension, which were initially associated with cardiovascular disease (CVD) (Brownson et al., 2016), have since been shown to be associated with many other chronic conditions, including cognitive decline and dementia (Baumgart et al., 2015; Adams and Grandpre, 2016), diabetes (Korat et al., 2014), asthma, arthritis, chronic obstructive pulmonary disease (COPD), cancer, kidney disease, depression, hypertension, and high cholesterol (Brownson et al., 2016; Adams et al., 2017). The presence of multiple risk factors is very common, and depending on which and how many are included, up to 92%–94% of all adults report at least one (Adams et al., 2016; Liu et al., 2016). As evidence of the impact of these risk factors accumulates, comparing the contributions of individual risk factors to common chronic conditions becomes more important. Population-attributable risk (PAR) is one such method (Brownson et al., 2016) which can be used when there is strong evidence of causality. PAR estimates take into account not only the relative risk of people with that risk factor developing the chronic condition, but also the prevalence of the RF in the population. Comparing PARs for different risk factors and chronic conditions can help inform decisions about which interventions might have the greatest potential to reduce the burden of illness.

Our objective in this current work was to study the impact of 7 potentially modifiable risk factors on 9 leading chronic conditions. The selected risk factors were consistent with “Life's Simple 7” used by the American Heart Association (Lloyd-Jones et al., 2010; Folsom et al., 2011): smoking, sedentary lifestyle, inadequate fruit and vegetable consumption, obesity, diabetes, hypertension, and high cholesterol, with the latter 3 also considered chronic conditions. The other chronic

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[1] Abbreviations: AOR: adjusted odds ratio; BRFSS: Behavioral Risk Factor Surveillance System; CVD: cardiovascular disease; COPD: chronic obstructive pulmonary disease; PAR: population-attributable risk; RF: risk factor.

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conditions studied were asthma, arthritis, CVD, COPD, cognitive impairment, and chronic kidney disease. Specific objectives were to 1) test the hypothesis that a linear dose-response gradient exists between each outcome and increasing numbers of risk factors; 2) determine adjusted odds ratios (AORs) for each separate risk factor for each outcome along with the prevalence of each risk factor in order to estimate PAR; and 3) explore the possibility of regional variation which should be considered when planning interventions. Because our data would be from a cross-sectional survey, we would use results from other studies to provide evidence for causality (Brownson et al., 2016; Baumgart et al., 2015).

2. Methods

2.1. Data

We used publicly available (Behavioral Risk Factor Surveillance System (BRFSS) (2018a) data from 2017, with survey questions available on-line (Behavioral Risk Factor Surveillance System (BRFSS), 2018a). The BRFSS is a large, representative, state-based telephone survey of non-institutionalized U.S. adults (Behavioral Risk Factor Surveillance System (BRFSS), 2018a) and our data included 444,649 respondents ages ≥18 years in the 50 states and DC. In general, data have been shown to be comparable to results from national surveys based on self-reported behaviors (Nelson et al., 2001) with high validity and reliability for chronic disease measures (Pierannunzi et al., 2013). For all measures described below, responses of "don't know" or refusal to answer were excluded from analysis of the measure. The median response rate for cell phone and land line surveys combined was 47.2%, ranging from 33.9% in California to 61.1% in Utah (Behavioral Risk Factor Surveillance System, 2018b).

2.2. Risk factor measures

Risk factor measures were consistent with the 7 ideal cardiovascular health metrics used by the American Heart Association (Lloyd-Jones et al., 2010; Folsom et al., 2011). Because the BRFSS is a cross-sectional survey ever smoking was used in lieu of current smoking; ever smokers were respondents who smoked 100 cigarettes in their lifetime. Respondents who did not participate in any leisure time physical activity in the past month were considered sedentary. Obesity was a body mass index ≥30 based on self-reported height and weight. The latter 2 RFs are consistent with the "poor" category in the Folsom study (Folsom et al., 2011). Inadequate fruit and vegetable consumption was defined as consuming the combination < 5 times per day based on responses to 5 separate questions (excluding fried potatoes) and was the only measure of diet available on the BRFSS. RFs that could also be chronic conditions included hypertension, high cholesterol, and diabetes, each defined as "ever told by a doctor, nurse, or other health professional," except diabetes excluded women who were told only when pregnant.

Once unknowns were removed, final N's for the 7 separate RFs ranged from 389,200 for fruit and vegetable consumption to 443,870 for diabetes. Composite measures were generated that included all 7 RFs and the 6 RFs that excluded the RF which was also an outcome. Unknowns were removed from the composite measure if any of its components were unknown, resulting in final sample sizes of 358,218 for the measure including all 7 and 358,573–361,505 for the measures that included only 6.

2.3. Outcome measures

With the exception of cognitive impairment all chronic conditions were defined as "ever told …" and included CVD (heart attack, coronary heart disease or stroke), current asthma (ever told and still have it), COPD, arthritis, and kidney disease. Cognitive impairment was defined as a "yes" response to "Because of a physical, mental, or emotional problem, do you have difficulty remembering, concentrating, or making decisions?" This question has been asked since 2008 by the Census Bureau and is now a standard disability question on federal surveys (US Census Bureau and American Community Survey (ACS)). This measure should not be considered cognitive decline because the question lacks a time frame (Jessen et al., 2014; Rabin et al., 2015).

2.4. Other variables

Demographic measures included gender, age (18–24, 25–29, 30–34, 35–39, 40–44, 45–49, 50–54, 55–59, 60–64, 65–69, 70–74, 75–79, and 80 years and older), self-reported race/ethnicity (non-Hispanic white, Black or African American, Hispanic of any race, American Indian/Alaska Native, Asian, and other), education (college graduate, some college, high school graduate, < high school), household income (≥$75,000, $50,000–$74,999, $25,000–$49,999, $15,000-24,999, < $15,000, and unknown), and census region (West, Northeast, Midwest, and South) (US Census Bureau).

2.5. Statistical analysis

Stata version 14.1 (Stata Corp LP, College Station, TX) was used for analysis in 2018 to account for the complex sample design of the BRFSS and used weights and stratum variables supplied in the data set. Data were weighted to account for the probability of selection, and further adjusted through a "raking" process to represent the adult population in each state by age, gender, race/ethnicity, marital status, education, home ownership, and telephone source. Point estimates and 95% confidence intervals were determined for each chronic condition by the number of risk factors reported (0–6 for the 3 outcomes that were also RFs or 0–7 for others). Mean numbers of risk factors were determined. PARs were estimated using Levin's formula (Rückinger et al., 2009) and adjusted odds ratios (AOR) obtained from logistic regression instead of unadjusted relative risk. PARs were determined using all relevant RFs and also limited to RFs shown in other studies to be causally associated with the outcomes (Brownson et al., 2016; Baumgart et al., 2015). A combined PAR was computed using the following formula to avoid totals > 100% (Barnes and Yaffe, 2011; Rowe et al., 2004): Combined PAR = 1 − (1 − PAR1) ∗ (1 − PAR2) ∗ (1 − PAR3)…

3. Results

Prevalence of the separate chronic conditions and risk factors and the composite measure of 7 risk factors are shown in Table 1 indicating that 95.2% of respondents reported at least one risk factor, while 72.3% had ≥2, and 45.8% reported ≥3. For the 9 chronic conditions, 60.2% reported ≥1 and 35.8% of all adults reported ≥2. The mean number of risk factors was 2.54 (95% CI 2.53–2.55) and increased across regions from the West (2.33), Northeast (2.48), Midwest (2.61) to the South (2.66). The distribution of the 7 risk factors for each number of risk factors in the composite measure is shown in Supplemental Table S-1 indicating that inadequate fruit and vegetable consumption was consistently the most prevalent while the least prevalent was diabetes. The mean number of chronic conditions was 1.34 (1.33–1.35) ranging from 1.20 in the West, 1.31 in the Northeast, 1.37 in the Midwest and 1.42 in the South.

Results of the unadjusted associations of each outcome with increasing numbers of risk factors in the appropriate composite measure (Supplemental Table S-2) show the point prevalence of each outcome was highest for the greatest number of risk factors (either 6 or 7). Unadjusted rates were higher in the South and lower in the West for COPD, diabetes, CVD, high cholesterol, cognitive impairment, and hypertension. Kidney disease also had high rates in the South but lower rates in the Northeast while low rates in the West were also found for arthritis and asthma (not shown).

Adjusted odds ratios (AOR) for the highest number of risk factors in the model (6 or 7) ranged from 4.5 (95% CI 3.4–5.8) for asthma to 30.4

Table 1
Risk factors and chronic conditions among all adults, 2017 Behavioral Risk Factor Surveillance System. N = 358,218.

Risk factor measures	Percent	95% CI
Obesity	30.1	29.8–30.4
Ever smoking	40.4	40.1–40.7
Sedentary lifestyle	26.6	26.3–26.9
Eat < 5-a-day	84.1	83.8–84.3
High cholesterol[a]	29.1	28.8–29.4
Hypertension[a]	32.4	32.1-32.7
Diabetes[a]	10.8	10.6-11.0
Any of 7 above	95.2	95.1–95.4
Measure with all 7 risk factors above		
Have none of above risk factors	4.8	4.6–4.9
Any 1	23.0	22.7–23.3
Any 2	26.5	26.2–26.8
Any 3	20.8	20.5–21.1
Any 4	13.8	13.5–14.0
Any 5	7.5	7.3–7.7
Any 6	3.0	2.9–3.1
All 7	0.7	0.7–0.8
Chronic conditions		
Asthma	9.1	8.9–9.2
Arthritis	24.6	24.3–24.8
Cardiovascular disease	8.5	8.3–8.7
Cognitive impairment	11.3	11.1–11.5
Chronic obstructive pulmonary disease (COPD)	6.6	6.4–6.7
Kidney disease	3.2	3.0–3.3
Any of 9 chronic conditions[b]	60.2	59.9–60.6

[a] Also considered chronic condition.
[b] Includes diabetes, high cholesterol, and hypertension.

Table 2
Summary of results from logistic regression.[a]2017 Behavioral Risk Factor Surveillance System N~ 348,000.

Ranked by AOR of highest # of risk factors[a] (6 or 7) vs. 0 RFs		
Outcome	AOR (CI) for most RFs v. 0 RFs	AOR (CI) for age 80+ v. 18–24 years
Diabetes[b]	30.4 (23.5, 39.4)	14.1 (11.0, 18.0)
Hypertension[b]	23.1 (18.8, 28.5)	14.9 (13.2, 16.9)
COPD	17.3 (12.1, 24.9)	3.3 (2.7, 3.9)
CVD	11.4 (8.7, 15.0)	29.8 (20.7, 43.0)
Kidney disease	11.3 (7.4, 17.1)	5.3 (3.7, 7.5)
High cholesterol[b]	9.9 (8.3, 11.8)	10.6 (9.2, 12.2)
Cognitive impairment	9.7 (7.5, 12.7)	0.36 (0.31, 0.41)
Arthritis	7.3 (5.9, 9.1)	19.7 (17.0, 22.9)
Asthma	4.5 (3.4, 5.8)	0.36 (0.31, 0.42)

AOR: adjusted odds ratio; CI: 95% confidence interval; COPD: chronic obstructive pulmonary disease; CVD: cardiovascular disease.
[a] Model includes demographics, region, and composite measure of ever smoking, obesity, sedentary lifestyle, eating fruits and vegetables < 5×/day, hypertension, high cholesterol, and diabetes.
[b] Only 6 risk factors because one is outcome measure.

(23.5–39.4) for diabetes (Table 2). AORs for ages 80 years and older vs. ages 18–24 years were significantly higher than those for maximum number of risk factors for CVD and arthritis, while AORs were < 1.0 indicating an inverse association with increasing age for cognitive impairment and asthma.

In a few cases, RFs that were shown to be causally associated with an outcome did not have AORs > 1.0 in our logistic regression model so the resulting PAR estimate was 0. These are noted by a footnote to Table 3. Other AORs ranged from 1.1 to 3.5 (Supplemental Table 3). For regions, unadjusted results for diabetes, hypertension, high cholesterol, COPD, and CVD were confirmed by logistic regression as having highest rates in the South and lowest in the West. Unadjusted results for asthma were also confirmed as highest in the Northeast and lower in the South. However none of the outcomes had highest unadjusted rates in the West, but cognitive impairment and kidney disease each had AORs which were apparently highest in the West (with West as referent), while adjusted results for arthritis were similar for all regions.

The AORs for the separate risk factors were used to estimate the population-attributable risk in different ways (Table 3). Using only RFs shown to be causally associated with the outcome, the combined PARs ranged from 13% or 16% for asthma to 60% for CVD, depending on whether all RFs or only those with evidence of causality were included in the logistic regression model used to obtain AORs. In both these cases, obesity and ever having smoked contributed the most overall to attributable risk (Table 3A & B.), with each contributing to 5–6 outcomes. When including all RFs in PAR estimates, whether causality was confirmed or not, hypertension was the largest contributor to attributable-risk (Table 3C.).

4. Discussion

This study builds on a large body of evidence showing risk factors associated with CVD are also associated with other chronic conditions (Brownson et al., 2016; Baumgart et al., 2015; Adams and Grandpre, 2016; Korat et al., 2014; Adams et al., 2017). By limiting results to RFs shown (Brownson et al., 2016; Baumgart et al., 2015) to have causal associations with our selected outcomes, results found total PARs attributed to 7 RFs ranged from 13% for asthma to 60% for CVD, with the average for the 9 outcomes 37.2–41.5%. Obesity and ever smoking contributed the most overall and together contributed to all 9 outcomes. Summarizing PAR results for these 9 outcomes and 7 risk factors permits comparisons that are not available in most other studies. The vast majority of adults (95.2%) reported one or more of the 7 risk factors in this study while > 2/3 reported 2 or more. Over 60% of respondents reported one or more of the chronic conditions and 36% reported 2 or more. Our hypothesis that a linear dose-response gradient exists between each outcome and increasing number of risk factors was confirmed, suggesting that the effect of these separate risk factors is additive and emphasizing their importance.

Attributable risk estimates from this study are consistent with results from other studies with widely varying methods. For the year 2000, tobacco use was identified as the leading cause of mortality responsible for 18% of all US deaths, followed by poor diet and physical inactivity (Mokdad et al., 2004). A more recent study that addressed the lifestyle factors of smoking, diet, exercise, and weight, plus alcohol consumption (Li et al., 2018) found life expectancy 12–14 years longer for adults with none of the 5 risk factors. Their estimate of population-attributable risk for all-cause mortality of 60.7% was consistent with the estimates in our cross-sectional study, considering they used somewhat different methods and risk factors, and recognizing that people can have > 1 chronic condition (as 35.8% did in our study) but only a single cause of death. Agreement of our PAR estimates with those from other studies which did not use mortality as an outcome was varied. For example, we did not find obesity to be associated with CVD or kidney disease, so our PARs in those cases were 0; this finding differed from the relevant results of other studies (Brownson et al., 2016). However our results appear to be consistent with the ranges of PARs from other studies (Brownson et al., 2016; Barnes and Yaffe, 2011).

Our sources for risk factor causality (Brownson et al., 2016; Baumgart et al., 2015) relied on multiple studies and represent summaries of the best evidence available. There may be other studies that show causality for additional risk factors for one or more of our selected outcomes that were not included in these summaries. We found no summary of PARs for the wide range of outcomes as reported here. We also note that the PARs can vary for different populations, e.g. those of different age, race, gender, ethnicity, and/or socioeconomic status.

Population-attributable risk presented this way can help inform strategy decisions. From a public health perspective, these 7 risk factors together contributed to an average 37.2–41.5%% of the burden of 9

Table 3
Population-attributable risk, 2017 Behavioral Risk Factor Surveillance System N = 358,218.

Risk factor > outcome	Diabetes	Hypertension	High cholesterol	Ever smoked	Sedentary	Obese	Eat < 5	Combined[a]
A. Using only RFs shown to be causally associated with outcomes								
Cardiovascular disease	6.7%	29.3%	19.9%	19.9%	5.1%	[b]		59.8%
Cognitive impairment	4.6%	14.7%		24.9%	10.7%	5.6%	7.7%	52.4%
Diabetes				3.7%	6.7%	37.8%		45.4%
Hypertension					5.1%	30.9%		34.4%
Chronic obstructive pulmonary disease				50.9%				50.9%
Kidney disease	14.0%	35.2%		6.8%		[b]		48.1%
High cholesterol	15.1%			7.4%	1.9%	11.5%	11.4%	39.4%
Arthritis					8.1%	20.5%		26.9%
Asthma						16.4%		16.4%
Total	40.5%	79.2%	19.9%	113.4%	37.4%	122.7%	19.1%	
B. All risk factors entered in model but only those with confirmed causality are used								
Cardiovascular disease	6.7%	29.7%	19.8%	20.2%	4.8%	[b]		60.1%
Cognitive impairment	3.6%	11.6%		24.6%	10.3%	5.2%	7.9%	49.7%
Diabetes				[b]	5.6%	31.4%		35.3%
Hypertension					3.9%	26.3%		29.1%
Chronic obstructive pulmonary disease				50.6%				50.6%
Kidney disease	12.9%	32.1%		6.2%		[b]		44.5%
High cholesterol	11.5%			6.4%	[b]	6.4%	9.7%	30.0%
Arthritis					6.8%	16.7%		22.3%
Asthma						13.1%		13.1%
Total	34.8%	73.4%	19.8%	108.0%	31.4%	99.0%	17.6%	
C. All risk factors entered in model, and all with AORs > 1.0 are included								
Cardiovascular disease	6.7%	29.7%	19.8%	20.2%	4.8%	[b]		60.1%
Cognitive impairment	3.6%	11.6%	13.1%	24.6%	10.3%	5.2%	7.9%	56.3%
Diabetes		54.5%	27.2%	[b]	5.6%	31.4%		78.6%
Hypertension	12.9%		32.3%	6.1%	3.9%	26.3%	7.8%	63.8%
Chronic obstructive pulmonary disease	2.3%	11.0%	10.7%	50.6%	13.7%	5.8%		68.8%
Kidney disease	12.9%	32.1%	9.1%	6.2%	9.7%	[b]		54.5%
High cholesterol	11.5%	58.0%		6.4%	[b]	6.4%	9.7%	70.6%
Arthritis	1.9%	15.9%	10.9%	14.7%	6.8%	16.7%		51.2%
Asthma	3.1%	10.4%	6.6%	10.7%	5.3%	13.1%		40.4%
Total	55.1%	223.2%	129.8%	139.5%	60.1%	104.7%	25.4%	

Abbreviation: Eat < 5: eat fruits and vegetables < 5×/day.
[a] Combined PAR = 1 − (1 − PAR1) ∗ (1 − PAR2) ∗ (1 − PAR3)…
[b] Causality confirmed but AOR not > 1.0 in our model.

chronic conditions. We used a formula (Barnes and Yaffe, 2011) to assure that the sum of the PARs for each outcome was < 100%; using simple summation would have produced an even higher average. The formula we used assumes that risk factors are independent and that an additive relationship exists between them. Our results with different logistic regression models suggest the risk factors may be independent. We also found linear dose response gradients suggesting an additive relationship. But to be safe, these combined PAR estimates should be considered as maximums. In terms of risk factors, the results indicate each of the 7 risk factors contribute to between 1 (high cholesterol) and 6 outcomes, with smoking and obesity together contributing to all 9 outcomes and the most overall. Some RFs found to be causally associated (Brownson et al., 2016; Baumgart et al., 2015) with certain outcomes did not have AORs > 1.0 in our analysis so the PARs were considered to be 0 (Table 3). These RFs include obesity for CVD and kidney disease, smoking for diabetes, and sedentary lifestyle for high cholesterol, with smoking and sedentary lifestyle dependent on whether all 7 RFs were included in the logistic regression model. This suggests there may be some interaction between RFs or other variables in the model affecting those results. In general, however, there was good agreement between Table 3A and B, suggesting little interaction.

From a geographical standpoint, the regional results from this study were somewhat unexpected. Logistic regression confirmed higher rates in the South and lower rates in the West for 5 outcomes, and higher rates in the Northeast and lower rates in the South for asthma. Unadjusted results for cognitive impairment, kidney disease, and arthritis (the latter of which had similar adjusted rates for all regions) were not confirmed. Demographically, cognitive impairment and asthma were the only outcomes which showed an inverse association with increasing age (Table 2). This suggests that age, income, or other variables in the model are confounding the results for some outcomes. However, this does not alter the finding that adults in the South reported more risk factors and chronic conditions than adults in the other 3 regions and had higher AORs for 5 outcomes and therefore might deserve extra attention when planning interventions. Our regional results appear to be broadly consistent with studies on CVD mortality, which is a leading cause of death in the US (Singh et al., 2015). Between 1969 and 2011, CVD mortality declined fastest in the Northeast and slowest in the Southeast and Southwest with the geographical disparity widening during that time interval. The geographical differences in mortality reflected disparities in socioeconomic conditions and behavioral risk factors (Singh et al., 2015).

Taken together, our findings indicate that interventions to address all 7 risk factors and 9 outcomes may require innovative approaches. Because each RF was found to contribute toward attributable-risk for at least one outcome, none should be ignored. Existing programs that have been shown to be effective in addressing any of the risk factors should be continued. But the results suggest that emphasis might be placed on addressing smoking and obesity. Smoking is a behavior, often initiated by young adults and difficult to quit, while obesity is actually an outcome resulting from other risk factors including poor diet and physical inactivity (Brownson et al., 2016). Smoking rates are already declining (Jha et al., 2013; Pernenkil et al., 2017), while obesity rates are increasing quite steadily (Pernenkil et al., 2017), suggesting that current interventions are not particularly successful. To effectively address the challenge presented by chronic diseases, the Centers for Disease Control

and Prevention (CDC) (Bauer et al., 2014) and the US Preventive Services Task Force (Patnode et al., 2017) provide some guidance. CDC strategies are based on collaboration between public health and the healthcare system with interventions including environmental changes, clinical preventive services, patient counseling, and community resources to help maintain ongoing management of chronic conditions (Bauer et al., 2014). The Task Force recommendations focus on behavioral counseling to address sedentary lifestyle and improve diet (Patnode et al., 2017) which should also address obesity. In their study of a wide range of interventions, they found the most promising results for short term interventions (6–12 months) which resulted in improvements in body mass index, waist circumference, blood pressure, cholesterol, dietary intake, and physical activity. Higher intensity interventions showed better results. Addressing obesity may require increased awareness of the results of studies showing the clear association between obesity and an array of adverse outcomes. This must be accomplished while recognizing that obesity prejudice is not acceptable. It is the consequences of obesity that are the problem, not obesity per se.

4.1. Study limitations

There are several limitations to this study. Because data are from a cross sectional survey, there is no way to know if risk factors were present before the development of the chronic condition. For smoking, all persons who ever smoked were grouped together with no differentiation for the length of time smoked or how long it might have been since they quit. Because of this, we might be somewhat overstating the attributable risk for smoking. Only non-institutionalized adults are surveyed so adults in long term care who may be even more likely than those studied to have these conditions were excluded. However they would also be unlikely targets of any proposed interventions. Adults who are physically or mentally unable to respond to a survey are also excluded, which may omit some potential respondents and intervention targets (Adams, 2017). Persons in households with no telephones are also excluded although it is unclear what affect that might have on results. Data are self-reported and reliability and validity can vary for different measures tested (Nelson et al., 2001; Pierannunzi et al., 2013). Risk factor measures such as smoking, height and weight used in obesity determination, sedentary lifestyle, and fruit and vegetable consumption were found to have moderate to high validity (Nelson et al., 2001) although the fruit and vegetable questions have since been modified. And as long as a respondent was told they had a chronic condition, validity was high but some people may not be aware of a diagnosis (Pierannunzi et al., 2013). Because 35.8% of study adults reported 2 or more chronic conditions, each outcome is unlikely to only represent that condition but may include unknown representation of other chronic conditions with different characteristics and risk factors. Other risk factors not available on the survey might affect results if they had been included. For example, too much or too little sleep has been identified as a risk factor for CVD and diabetes (Brownson et al., 2016) but a measure of sleep was not available for all states. Thus we acknowledge that these PAR estimates are only estimates and are especially dependent on how many and which risk factors are included and the population studied.

5. Conclusion

Using results from other studies that identified risk factors with causal associations (Brownson et al., 2016; Baumgart et al., 2015), population-attributable risk estimates found that ever-having smoked and obesity contributed the greatest amount to CVD, cognitive impairment, asthma, arthritis, diabetes, kidney disease, COPD, hypertension, and high cholesterol combined. Most (95%) US adults reported ≥ 1 and over 72% reported ≥ 2 of the 7 risk factors and 60% reported one or more of the 9 chronic conditions. Results also show that the more risk factors a person has, the greater was the risk, which implies that successful approaches will need to address multiple risk factors. Regional results indicate that the South might gain more potential benefits from successful interventions but the effectiveness of any program is critical. The combination of the relatively high population-attributable risk for most of the risk factors, the variety of chronic conditions with which they are associated, the number of adults affected, and the dose-response gradients involved, underscore the magnitude of the burden that could potentially be reduced by effective interventions. Broad based, comprehensive programs will likely be needed to successfully modify behavior and reduce the burden of these chronic conditions.

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Conflict of interest

The authors declare there are no conflicts of interest.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.ypmed.2019.01.006.

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